GeoMorph™ Sampling and Analysis Plan

Upper Tittabawassee River
Midland, Michigan

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1. INTRODUCTION

The Tittabawassee River has been the focus of several investigations over the past several decades. These studies have primarily been directed towards gaining an understanding of the distribution of contaminants in the river water, sediments, fish, and more recently floodplain soils. In December 2005, the Tittabawassee River and Floodplain Remedial Investigation Work Plan (RI/WP) (CH2M Hill, 2005c) was submitted to the Michigan Department of Environmental Quality (MDEQ) and United States Environmental Protection Agency (USEPA). The RI/WP proposed a phased approach for site characterization and incorporated a statistically based predictive model.

In March 2006, the Dow Chemical Company (Dow) requested that Ann Arbor Technical Services, Inc. (ATS) review the RI/WP, existing data, and historical information and prepare a *GeoMorph*™ Sampling and Analysis Plan (SAP) for the investigation of the upper six miles of the Tittabawassee River. This document presents the *GeoMorph*™ approach to address the investigation of contaminated sediments of the Upper Tittabawassee River (UTR). It includes the objectives and overall approach for a geomorphic-based sediment and soil investigation. When implemented, this SAP will provide a geomorphology-based characterization of the UTR sufficiently comprehensive to evaluate risk management options. An overview of the Upper Tittabawassee River is shown in Attachment B, Figure 1.

1.1 OBJECTIVES AND DELIVERABLES

This SAP is intended to provide a description of a geomorphic approach to investigate and evaluate the potential constituents of interest (PCOI) that may be present in sediments and soils along the UTR. These PCOI include chlorinated dioxins, chlorinated furans, and other chemicals. The *GeoMorph*™ process is a comprehensive fate and transport methodology, incorporating fundamental information of PCOI environmental chemistry with fluvial processes and river geomorphology together with contaminant release history and anthropogenic influences along the river system. The objective of this document is to provide a comprehensive characterization of in-channel and floodplain sediments and soils along the UTR. Deliverables of this SAP will include:

- An assessment of the relevant physical and chemical properties of the PCOI;
- Detailed topographic mapping of the project area with geomorphic features;
- Historical aerial photographic analysis for the relevant period;
- Detailed geomorphic feature mapping;

- In-channel sediment inventory, confirmatory sediment poling, and core sampling;
- Summary tables and concentration maps of the sediment and soil sampling information, with all locations described by reach and stationing coordinates;
- "Existing condition" surface-weighted average concentration (SWAC) maps using geomorphic polygons.

1.2 REPORT ORGANIZATION

This SAP is organized into the following sections:

Section 1 – Introduction: presents the objectives and approach for this SAP.

Section 2 – Background: summarizes the project area, previous investigations, and introduces the *GeoMorph*™ investigation process used in the design of this SAP.

Section 3 – Current Conditions: summarizes environmental information relevant to establishing the scope of this SAP for the UTR. This includes descriptors of the study area, potential sources of hazardous substances, and extent of media potentially impacted by releases of hazardous substances based on available data.

Section 4 – Conceptual Site Model (CSM): presents the CSM that integrates the information necessary to understand how furans, dioxins, and other Target Analytes (TA) move through the study area and come into contact with the environment.

Section 5 – Focused Investigation Approach: identifies the data collection needs and describes the overall approach that will be used to address the objectives of a *GeoMorph*™ SAP for the UTR.

Section 6 – Schedule: proposes the schedule for this SAP and planned future deliverables.

Section 7 – References: lists the references cited in this SAP.

Section 8 – Glossary: lists terms and related definitions used in this SAP.

Section 9 – Acronyms and Abbreviations: lists the acronyms and abbreviations used in this SAP.

2. BACKGROUND

This section provides an overview of the project background and a brief description of the literature review that was undertaken to identify and document existing sources of data and analysis on the UTR Project.

2.1 PROJECT AREA OVERVIEW

The Tittabawassee River is a tributary to the Saginaw River, draining 2,600 square miles of land in the Saginaw River Watershed. It is one of four tributaries that comprise approximately 84 percent of the total Saginaw River drainage area (MDNR, 1988). The tributary drainage areas for these four rivers includes: Tittabawassee, Shiawassee, Flint, and Cass. The Tittabawassee has the largest drainage area covering 39 percent of the total area draining to the Saginaw River.

There are a number of dams on the upstream portion of the Tittabawassee River. The dams are located at Secord, Smallwood, Edenville, Sanford, and Midland (Dow). Below the Dow Dam, the river is free flowing to the confluence with the Saginaw River.

The Tittabawassee River is the receiving water from various industrial and municipal waste water discharges. Some discharge directly into the river, and some discharge into the major tributaries of the Tittabawassee River: the Salt, Tobacco, and Chippewa Rivers. Past industrial inputs include wastes from chemical, plastics, can manufacturing, and photographic industries (Rossman, 1983).

For communication purposes, ATS has established a numerical stationing system for the Tittabawassee River. The numerical stationing was established down the middle of the Tittabawassee River at 50-foot intervals. The river stationing is depicted graphically in Attachment C, Figures 1 through 18. In addition, reach designation based on channel slope, channel width, geomorphic features, and sinuosity have been established for the UTR and are summarized in the following table and presented in Attachment B, Figure 2.

Reach Designation	Stationing	Reach Length (ft)
Reach A	0+00 to 12+00	1,200
Reach B	12+00 to 37+50	2,550
Reach C	37+50 to 46+50	900
Reach D	46+50 to 59+25	1,275
Reach E	59+25 to 81+00	2,175
Reach F	81+00 to 115+00	3,400
Reach G	115+00 to 141+00	2,600
Reach H	141+00 to 163+50	2,250
Reach I	163+50 to 185+50	2,200
Reach J	185+50 to 196+50	1,100
Reach K	196+50 to 233+50	3,700
Reach L	233+50 to 261+50	2,800
Reach M	261+50 to 286+00	2,450
Reach N	286+00 to 320+00	3,400
Reach O	320+00 to 335+50	1,550

2.2 PREVIOUS INVESTIGATIONS/DOCUMENT REVIEW

ATS performed a limited review and re-analysis of the available environmental data/information on the Upper Tittabawassee River. Several environmental data collection studies have been conducted in the Tittabawassee River area since 1970. The authors of these studies include Dow, Dow consultants, MDEQ, the U. S. Army Corps of Engineers, and USEPA, United States Geologic Survey (USGS), and others. The objective of these studies varied, ranging from general contaminant and sediment characterization to preliminary human health and ecological risk assessments. With such varied study objectives some of the information and data may not be optimal for data evaluation purposes and input into the *GeoMorph*™ process.

The purpose of the background data review was to evaluate the suitability of this information to the *GeoMorph*™ process. The means, methods, and procedures used to collect historical data were part of the data re-analysis. Data suitability was determined by reviewing procedures used to select sampling locations, sampling intervals, sediment description process, sample analysis process, analytical parameter selection, and sediment poling techniques. Additional information reviewed included available mapping, aerial photography, and river flow data. For this SAP a consistent process and uniform standards were used to assess the overall data quality.

Analytical data contained in the review documents were not assessed for quality. The suitability analysis assumed the quality assurance and quality control (QA/QC) aspects of all analytical data points and data sets were consistent with USEPA guidance and valid for the intended purpose.

As general reference, the primary contributing source of information for Sections 2 though 4 of this SAP, was the December 2005, Tittabawassee River and Floodplain Remedial Investigation Work Plan (CH2M Hill, 2005c).

3. CURRENT CONDITIONS

This section presents a description of current conditions on the Tittabawassee River and floodplain. It summarizes environmental information relevant to establishing the scope for the characterization of the Upper Tittabawassee River, including a description of the physical characteristics of the study area, a summary of the potential historical sources of hazardous substances, and a preliminary assessment of media in the UTR study area that may have been impacted by releases of hazardous substances based on available data.

This section incorporates information from a variety of previous investigations, including the 2005 Tittabawassee River Floodplain Scoping Study (Scoping Study) (CH2M Hill, 2005a) and the December 2005, Tittabawassee River and Floodplain Remedial Investigation Work Plan (CH2M Hill, 2005c).

3.1 PHYSICAL SETTING

The characteristics of the Tittabawassee River valley influence the distribution of constituents released from the Midland Plant, potential exposure to those constituents, and the development and evaluation of potential remedial alternatives. An overview of the physical setting of the study area is presented below.

3.1.1 Geology and Hydrogeology

The following sections briefly describe the geology and hydrogeology of the Tittabawassee River valley.

3.1.1.1 Geology

Glacial deposits are present at the ground surface in the region of the Tittabawassee River and floodplain. South of Midland, Pennsylvanian-age sedimentary bedrock is overlain by 150 to 400 feet of unconsolidated glacial deposits. The glacial sediments were deposited during the Pleistocene Epoch as glaciers advanced and retreated across the Midland area (Dow, 2002). The glaciers deposited glacial till composed of ground rock on the landscape, with silt, sand and gravel deposited in melt water channels. Subsequent glacial advances compressed the till with continental ice sheets up to 1-mile thick, and additional layers of glacial sediment were deposited during subsequent retreats. After the final glacial advance came to a close, melt water ponded at the edge of the retreating ice, forming ice marginal lakes. Large lakes formed in areas where the land was depressed from the weight of the glacier or where the glaciers blocked natural drainage patterns. Nearshore sand layers and small dunes were deposited on top of the lacustrine (lake) bottom clay-rich sediments as the shorelines retreated (Dow, 2002). These lakebed clay and sand layers form the primary surficial deposits in the Tittabawassee River and Floodplain study area, while the till is present at the river channel in some areas.

The Tittabawassee River has eroded through the surficial sand deposits and much of the lakebed clay units to form the floodway. In places the Tittabawassee River has eroded down to the glacial till deposits. The lakebed clay and the glacial till deposits represent materials deposited before any modern human activity in the area. Within the floodway, fluvial sand, silts, and clays have been deposited by the Tittabawassee River since the retreat of the glaciers from this area thousands of years ago. A small fraction of these fluvial deposits have been deposited during the last hundred years.

3.1.1.2 Hydrogeology

The Midland Plant is at the northwestern end of the Tittabawassee River and floodplain study area. Although limited soil boring information is available for the floodplain between Midland and the confluence of the Tittabawassee and Shiawassee Rivers, drillers' logs filed with the state for the installation of domestic water wells indicate that hydrogeologic conditions in the floodplain are similar to those in Midland. Additionally, limited drilling and soil sampling were conducted in several areas along the Tittabawassee River floodplain during several recent field events (CH2M Hill, 2005a; LTI, 2005a).

Descriptions of the hydrogeologic units below are based on information provided in Dow's 2002 License reapplication (Dow, 2002). Hydrogeologic units, from deepest to shallowest, are as follows: bedrock, the Regional Aquifer, glacial till, lakebed clay, and surface sands. Groundwater contained in bedrock occurs primarily in sandstone layers. The potentiometric head in the bedrock aquifer is higher than the head in the Regional Aquifer, resulting in an upward hydraulic gradient. The Regional Aquifer overlies bedrock in some areas and consists of well-sorted sands and gravels inter-layered with silt and clay seams. The low permeability of the overlying glacial till causes the Regional Aquifer to behave as a confined aquifer with an artesian head. Artesian conditions are common to the southwest of the Tittabawassee River because of the generally lower ground elevation.

Groundwater is present throughout the glacial till at saturation, although the extreme compaction of this unit has reduced effective porosity and permeability. Sand bodies of significant size, generally referred to as glacial till sands, occur in the glacial till. Glacial till sands are highly variable in length, thickness, and vertical location within the glacial till, and are relatively more permeable than the till.

The lakebed clay is generally considered an aquitard, although some water is contained in thin, discontinuous silt layers interbedded with the lakebed clay. The lakebed clay acts as a barrier to downward movement of groundwater.

Where the surface sands overlie the lakebed clay, the sands form an unconfined aquifer. Where present, the groundwater in the surface sands varies in both quantity and quality.

The majority of households located on or adjacent to the Tittabawassee River floodplain obtain their water from municipal systems (MDEQ, 2003a). However, some residences south and east of Midland along the Tittabawassee River continue to acquire potable water from groundwater (MDEQ, 2003a).

3.1.2 Climate and Meteorology

The Midland area is characterized by a continental climate regime, with winter temperatures cold enough to sustain stable snow cover and relatively warm summer temperatures. The mean temperature for the area is 48 degrees Fahrenheit (°F). The minimum average temperature is 22°F (January), and the maximum average temperature is 72°F (July). Between 1896 and 2002, the Midland area's average monthly precipitation ranged between 1.4 inches (February) and 3.1 inches (September), with a monthly average of 2.3 inches and an annual average of 27 inches. Wind direction is typically to the east-northeast, regardless of season.

According to annual measurements recorded in Midland from 1950-1951 through 1979-1980, the average seasonal snowfall between October and April was 37 inches. During this period, 65 days per season averaged 1 inch or more of snow on the ground, but conditions varied greatly from season to season (MSCO, 2005).

3.1.3 Hydrology

The Tittabawassee River is a tributary to the Saginaw River, draining 2,600 square miles of land in the Saginaw River watershed. It begins in Roscommon and Ogemaw Counties, which are located approximately 26 miles to the north of Midland and Saginaw Counties. The Tittabawassee River flows south and southeast for a distance of approximately 80 miles to its confluence with the Shiawassee River approximately 22 miles southeast of Midland. The majority of the Tittabawassee River watershed upstream of Midland is forested or agricultural. The Pine and Chippewa Rivers are tributaries to the Tittabawassee River, and have similar drainage areas and flow contributions to the Tittabawassee River. Together, the Pine and Chippewa Rivers contribute approximately 40 percent of the Tittabawassee flow at Midland (MDNR, 1988).

Upstream of the Midland Plant, river flow is regulated by the Secord, Smallwood, Edenville, and Sanford Dams. The Dow Dam is located adjacent to the Midland Plant. Below the Dow Dam, the river is free flowing to its confluence with the Saginaw River. Tittabawassee River flow and water level fluctuate daily in response to releases from the Sanford Dam. The average and 100-year flood discharge for the Tittabawassee River based on data from 1937 to 1984 are approximately 1,700 cubic feet per second (cfs) and 45,000 cfs, respectively (Johnson Co., 2001). The term "100-year flood" is a statistical designation that represents a 1-in-100 chance that a flood of this size will occur in any given year (USGS, 1996). The relatively large ratio between the 100-year flood discharge and the long-term average discharge (26.5) indicates that the river is "flashy," or has a flow regime that is characterized by a rapid rate of change.

The average monthly discharge data for 1937-2003 for the Tittabawassee River 2,000 feet downstream of the Dow Dam ranged from approximately 600 cfs (in August) to 3,900 cfs (in March), with an average of 1,700 cfs. Discharge is typically highest in March and April during spring snowmelt and runoff. The maximum recorded historical crest of the Tittabawassee River occurred in 1986. A large storm in September 1986 produced up to 14 inches of rain in 12 hours. The discharge of the river near the Dow Dam reached nearly 40,000 cfs, and the river stage was 10 feet above flood stage at its crest (Deedler, Undated). Flows greater than 20,000 cfs have occurred in 22 of the 95 years between 1910 and 2004, with flows greater than 30,000 cfs occurring in 1912, 1916, 1946, 1948, and 1986. In March 2004, the river discharge reached approximately 24,000 cfs.

The Tittabawassee River floodplain is periodically inundated by floodwaters. Defining the extent of the floodplain for various flood recurrence intervals can be useful in investigating the potential extent of impact caused by deposition of suspended sediments from floodwaters. The extent of the estimated floodplain for flood recurrence intervals ranging from 1 to 500 years was modeled using Federal Emergency Management Agency (FEMA) hydraulic data and USGS topographic maps. In addition, aerial photographs of the Tittabawassee River from the Midland Plant to the confluence with the Saginaw River were taken during two recent flood events: the March 2004 event (an estimated 8-year event) and the April 2005 event (an estimated 1- to 2-year event). These aerial photos were used to generate a higher-resolution definition of flood extent during more frequent flood events. The extent of the FEMA estimated 100-year floodplains is shown in Attachment B, Figure 3.

3.1.4 Geomorphology

The Tittabawassee River valley is an area of relatively subdued topographic relief with water elevations decreasing from approximately 595 feet mean sea level (msl) near Midland to 560 feet msl at the confluence with the Saginaw River. Primary features of the river valley include a relatively broad, flat floodplain extending to a steep scarp rising to the upland. The upland areas adjacent to the river valley are typically 20 to 30 feet above the valley floor.

The geomorphology of the river from the confluence with the Chippewa River to 6 miles downstream includes an area of anthropogenic influences followed by a natural river environment. Floodplain and terrace development is limited by anthropogenic features in the first 3.5 miles downstream of the Chippewa/Tittabawassee confluence. The anthropogenic influences in this portion of the river are due to development associated with the City of Midland, Dow Chemical, and Consumer's Power. The downstream 2.5 miles is a natural river environment that includes floodplain and terrace development between the river and the upland scarp.

Topographic information was obtained on the study area in December 2003 using airborne Light Detection and Ranging (LiDAR) techniques. These data were used to create detailed topographic maps of the study area. The Tittabawassee River floodplain can be divided into two general areas based on the morphology of the river valley. The river valley in the northern part of the study area is characterized by relatively abrupt valley walls whereas the valley in the southern part of the study area is characterized by gentler slopes away from the river and much broader floodplains.

The Tittabawassee River channel varies from relatively straight upstream of Freeland, to a more sinuous system downstream of Freeland. Although the river exhibits a low-to moderate level of sinuosity throughout, many of the features of a meandering system are present.

Typical meandering rivers have a channel that winds back and forth across a river valley. In the river channel, erosion tends to occur on the outsides of river bends, forming cut banks, and deposition tends to occur on the insides of river bends, forming point bars. The Tittabawassee River has a number of these features and yet the anthropogenic features have inhibited the natural development along the upper reaches of the river. Depositional features commonly present on floodplains include levees, splays, and overbank deposits. Levees form along river banks where floodwaters overtop the banks and deposit coarse-grained material. Overbank deposits are found in low-lying areas of the floodplain where fine materials settle out of suspension following floods.

The Scoping Study (CH2M Hill, 2005a) included a general reconnaissance of physical conditions and geomorphic features in the areas sampled. Because hydrodynamic conditions influence development of geomorphic features along the river and on the floodplain, different grain size distributions are present in the geomorphic features. Relatively coarser-grained deposits are typically observed in features adjacent to the river formed by lateral accretion under higher velocity flow regimes (for example, point bars). Finer-grained materials are typically located at greater distances from the river channel and represent vertical accretion under low velocity flow regimes (for example, overbank deposits).

3.1.5 Sediment Characteristics

In late 2003, sediment probing and coring work was conducted along regularly spaced transects within the study area to characterize the composition and thickness of unconsolidated sediments in the Tittabawassee River (LTI, 2004b). Additional sediment core information was collected as part of the Scoping Study (CH2M Hill, 2005a). In addition, surface (0 to 4 inches) and subsurface (8 to 12 inches) samples from selected cores were analyzed for grain-size distribution, total organic carbon (TOC) content, and bulk density. The thickness of unconsolidated sediments in the riverbed ranged from 0 to greater than 12 feet, and typically was between 1.5 and 7.5 feet. The thickness of unconsolidated sediment was related to the morphology of the river. Unconsolidated sediments were thin or absent on the outside of bends where water depths were the greatest. Along straight sections of the river, the sediment thickness and water depths were more uniform.

Visual characterization of the sediment cores indicated that sand was the dominant sediment type throughout the river, particularly in surficial sediments. The survey did not identify any areas of surficial fine-grained sediments (that is, silt or clay) that might indicate low-energy depositional areas. Fine-grained sediments were found underlying sandy surface sediments at approximately 20 percent of the surveyed locations. Wood and other organic material were found in some cores. Sediment samples were composed primarily of medium and fine sand with a median TOC content of approximately 1 percent. The median silt and clay content was 5 percent. The sediment composition data indicate that the Tittabawassee River is a relatively high-energy system; that is, sufficient energy is available to transport fine-grained materials downstream. The sediment characteristics are directly affected by the periodic release of water from the Sanford Dam.

3.1.6 Sediment Transport

Soil and sediment transport processes include in-river solids transport through the water column, erosion and deposition of solids in the floodplain, and exchange between the river channel and floodplain under flood conditions. These processes are described in greater detail below.

3.1.6.1 In-River Solids Transport

Solid particles may be transported either in the water column as suspended solids or as bedload along the river bottom. Suspended solids are generally fine-grained materials such as silt and clay that may be transported considerable distances once suspended. Larger particles (sand and gravel) generally move along the bottom of the river as bedload, traveling for relatively shorter distances on a per-event basis. The movement of larger particles depends on the water velocity and therefore such particles may move largely during high-energy flood events.

On average, the Tittabawassee River has a suspended solids concentration of 30 milligrams per liter (mg/L), which is consistent with suspended solids concentrations in other tributaries of the Saginaw River (MDNR, 1988; MDNR, 1994). Concentrations as high as 85 mg/L have been observed during and after heavy precipitation events (LTI, 2004a). In October 2003, flow and solids monitoring of the river was initiated to improve the understanding of erosion, transport, and deposition throughout the river system (LTI, 2004a). These data provide a preliminary indication of solids transport through the system and allow construction of a simplified model of solids transport. Preliminary results indicate that most of the solids transported through the river originate in the watershed upstream of Midland. In the three high flow events measured in 2003-2004 and a smaller event observed in March/April 2005, no discernable net gain or loss of suspended solids load occurred between the Midland Plant and the confluence of the Tittabawassee and Shiawassee Rivers.

The sediment bed may be episodically affected by scour induced by winter ice formation and breakup. The Tittabawassee River typically experiences significant ice formation during the winter months, with periodic ice breakup during mid-winter thaws that elevate river flows. Ice breakup and movement might affect the sediment bed in several ways: by individual ice floes impacting the sediment bed, banks, and near-bank areas; by the formation of ice jams; and by the enhanced scour that can occur as river flow is diverted around or under ice jams. Ice jams can also cause overbank flooding and sediment deposition. All of these factors may affect the stability of the sediment bed and bank areas on the Tittabawassee River.

3.1.6.2 Floodplain Erosion and Deposition Processes

The majority of erosion and deposition is episodic in nature; consequently, sediment and floodplain soil movement is believed to occur primarily during periodic flood events. The amount or rate of erosion and deposition is dependent on the intensity of the flood event, with large events resulting in correspondingly larger amounts of floodplain soil and sediment movement. Higher flow events result in increased erosion and transport for two reasons: first, the increased shear stress exerted on surficial soils or sediments increases the rate of erosion, and second, the increased flow energy has a correspondingly greater capacity to move solids downstream.

Pilot studies were conducted to evaluate the potential effectiveness of radiological age dating (geochronology) and dendrogeomorphic techniques to evaluate net rates of floodplain soil deposition at various representative locations in the floodplain. Dendrogeomorphology consists of the measurement of soil accumulation above the root systems of trees. Geochronology relies on the evaluation of the relative abundance of naturally occurring and man-made radioactive elements in the soil column. These methods are complementary and should produce similar results. The results of these studies are provided in the pilot study reports (LTI, 2005a; LTI, 2005b).

The dendrogeomorphology and geochronology results indicate that soil accretion rates along the Tittabawassee River floodplain are on the order of 0.1 to 0.5 inches per year with an average of 0.17 inches per year, which equates to a range of approximately 1 to 4 feet of soil accumulation over the past 100 years. The geochronologic and dendrogeomorphic results are in close agreement. Accretion rates vary locally, and preliminary analyses suggest that they appear to be influenced by local geomorphic features, including topography, proximity to the river, and channeling.

The accretion rates described above are net rates, reflecting the results of erosion and deposition operating over many years. While the measurements to date show net accretion in the floodplain, it is likely that localized erosion has also occurred. For example, after the March 2004 flood event, recently eroded areas were visually apparent such as scour around fence posts, downstream of trees, and so on. However, available measurements suggest a general tendency of the floodplain to gain solids rather than lose them, and localized scour likely results primarily in local redistribution of soils and limited export from the floodplain.

Available measurements of solids loads to date are limited. Observations of solids transport in the river under flood events in 2003 and 2004 showed that the in-river solids loads measured at the upstream and downstream ends of the study area were not sufficiently different to indicate a clear gain or loss of load across the study area. This is consistent with observations of relatively slow floodplain accretion described above.

Bank undercutting, overhanging vegetation, and lateral retreat can be observed at a number of locations between Midland and the Saginaw River confluence. The steep banks and ongoing lateral retreat are a product of several factors, including the post-glacial rebound of the land surface in mid-Michigan and subsequent incising of the river; the "flashiness" of the river as evidenced by the high peak to average discharge ratio; and likely historical increases in peak discharge caused by land development changes in the watershed, including extensive logging in the 19th century.

Human activities have disrupted the natural fluvial system through the construction of various structures and the creation of cut-and-fill areas. These features alter river flow patterns, restricting erosion and deposition in some areas while causing erosion and deposition in others. Examples of man-made features that affect the natural fluvial system include bridges, elevated roadways, and railroads where fill was used to elevate them above the floodplain; other areas that were filled to elevate the land surface above the floodplain; erosion control features used to stabilize riverbanks, dams, and cut areas where floodplain materials were removed; hydrologic inputs from surface water discharge, water releases from dams and power plants; and agriculture fields where ridges are leveled and depressions filled over the years by plowing and tilling. The effects of these activities on erosion, deposition and the formation of geomorphologic features are area-specific.

3.1.6.3 River-Floodplain Exchange

As described above, measurements of in-river suspended sediment load and floodplain accretion in the Tittabawassee River valley show (1) a significant load of suspended solids that is transported by the river, primarily under high flow conditions, and (2) positive rates of accretion in the adjacent floodplain over time that suggest flood-driven net solids movement from the river to the floodplain. The process by which flow and solids pass from the river channel to the floodplain during the rise, peak, and recession of a typical flood event is complex and depends on many factors, including the magnitude of flow, the bathymetry of the river and topography of the floodplain, the amount of vegetation in the floodplain and its tendency to slow down the flow, and the characteristics of the solid particles themselves, including density, cohesiveness, particle size, and tendency to settle.

3.1.7 Land Development

Residential, commercial, and industrial development within the Tittabawassee River floodplain is limited because of periodic flooding historically. Current land development was evaluated within the floodplain and assigned to one of six categories similar to those used by the MDEQ for establishing generic cleanup criteria. The total acreage in each land development type in the estimated 100-year floodplain is summarized below. Land development classifications were established primarily by reviewing aerial photographs and using secondary information such as zoning and knowledge of local conditions. The following land development categories were defined:

- **Recreational/Undeveloped.** This category designates properties intended for regular outdoor recreational activities and/or property that is primarily in a natural state. Lands included in this category are developed parks, boat launches, picnic areas, athletic fields, golf courses, country clubs, shooting clubs, undeveloped private property, undeveloped parkland, and wildlife areas. (Total Acres = 4,500; Percent of Area = 57)
- **Agricultural.** This category is used for lands that are actively used for farming, including cropland, orchards, and grazing. (Total Acres = 1,700; Percent of Area = 22)
- **Residential.** This category includes all lands that are used predominately for residential purposes. These include single-family homes, condominiums, apartment buildings, and mobile homes. (Total Acres = 1,200; Percent of Area = 16)
- **Industrial.** This category is used for properties that contain manufacturing and other industrial facilities. Land is generally highly reworked and little surface soil is typically present. Examples of industrial land development include manufacturing facilities, power plants, and municipal wastewater treatment facilities. Waste disposal sites, such as open or closed landfills, were also included in this category. (Total Acres = 320; Percent of Area = 4.0)
- **Commercial I.** This category includes commercial or other properties that are commonly occupied by sensitive populations. This land development category includes schools, nursing homes, and hospitals. (Total Acres = 9.2; Percent of Area = 0.1)
- **Commercial II, III, and IV.** This category includes the MDEQ classifications for all other types of commercial properties, such as office buildings, retail, restaurants, banks, gas stations, car dealerships, and automotive repair shops. Land used for these purposes was combined into a single category for this evaluation. (Total Acres = 120; Percent of Area = 0.1)

The dominant type of land development in the Tittabawassee River floodplain is Recreational/ Undeveloped, which accounts for 57 percent of the estimated 100-year Floodplain area. These lands include a substantial amount of undeveloped private property and encompass a portion of the Shiawassee National Wildlife Refuge. Agricultural lands are the next largest land development category and account for approximately 20 percent of the estimated 100-year floodplain. Agricultural areas are typically found in the lower portions of the floodplain and are susceptible to flooding. Residential land development accounts for approximately 15 percent of the estimated 100-year floodplain. Residential structures are generally located at higher elevations, in areas that are not routinely flooded.

Local zoning ordinances indicate current and intended future land uses. In accordance with Part 201 regulations, application of cleanup criteria must be consistent with zoning. Information has been compiled on zoning in the study area. Each municipality establishes numerous zoning categories to meet local needs. To gain a general understanding of zoning in the study area, zoning was consolidated into five broad categories: agricultural, commercial, industrial, residential, and natural areas. Zoning was found to be generally consistent with the actual land development category in the Tittabawassee River floodplain.

Four of the eight political entities responsible for land development planning in the study area have created the following zoning categories intended to minimize the impacts of flooding and preserve the natural condition of the floodplain:

- Thomas Township: E-1 = Environmental Areas
- Tittabawassee Township: G-C = Greenbelt Conservation Floodplain
- James Township: FC-1 = Floodplain Consideration
- Saginaw Township: FC-1 = Floodplain Consideration

3.1.8 Water Body Use

Historically the Tittabawassee River has been used for industrial and recreational activities, although its shallow depth (generally between 3 to 11 feet) precludes use by watercraft other than small shallow-draft boats. Recreational fishing in the river below Midland is guided by a fish consumption advisory issued by the Michigan Department of Community Health as updated in 2005 (MDCH, 2004a and 2004b).

3.1.9 Ecology

The Tittabawassee River and floodplain lie within the northern hardwood region of the Eastern Deciduous Forest. The floodplain is located within the Saginaw Bay Lake Plain Regional Landscape Ecosystem, as established by the USGS (Albert, 1995). This regional landscape ecosystem is characterized by the prevalence of both upland and palustrine (wetland) native plant communities, including forests, swamps, marshes, and scattered prairies. Historically, fire, flooding, and wind are identified as the dominant disturbance regimes (Cohen, 2004).

The vast majority of native forest originally present in Saginaw and Midland Counties has been converted to anthropogenic uses (Albert, 1995). The largest remaining contiguous forest is located within the Shiawassee National Wildlife Refuge, which contains approximately 3,500 acres of forest (USFWS, 2001). The remaining forest patches within the Tittabawassee River floodplain are also generally in a mid-successional state (that is, in the mid-stage of growth following a natural disturbance). Using the Michigan Natural Features Inventory (MNFI) Community Classifications (Cohen, 2004), they can be classified as mesic northern forests. This broadly defined category is characterized by numerous regional, physiographic, and soil type variations; along with a varying dominance of conifers and hardwoods. Considering the species present at the Shiawassee National Wildlife Refuge, it is apparent that lowland and upland hardwood stands are dominant in the Tittabawassee floodplain. The Refuge's Comprehensive Conservation Plan identifies maple, oak, hickory, ash, willow, elm, and cottonwoods (USFWS, 2001). Hardwood stands within the mesic northern forest tend to have a defined shrub layer and a very diverse herb layer (Cohen, 2004). Shrubs species generally present in mesic northern forest include striped maple *(Acer pennsylvanicum)*, mountain maple *(Acer spicatum)*, alternate-leaved dogwood *(Cornus alternifolia)*, beaked hazelnut *(Corylus cornuta)*, leatherwood *(Dirca palustris)*, fly honeysuckle *(Lonicera canadensis)*, wild gooseberry *(Ribes cynosbati)*, red elderberry *(Sambucus pubens)*, Canada yew *(Taxus canadensis)*, and maple-leaf viburnum *(Viburnum acerifolium)*. Herbaceous plants generally present in mesic northern forest include various baneberry *(Actaea)*, trillium *(Trillium)* and sedge *(Carex)* species, jack-in-the-pulpit *(Arisaema triphyllum)*, bunchberry *(Cornus canadensis)*, Solomon's seal *(Polygonatum pubescnes)*, star flower *(Trientalis borealis)* and an array of ferns and mosses. Also found in this forest type is the presence of chlorophyll-free seed plants such as Indian pipes *(Monotropa)*, coral root *(Corallorhiza)*, and beech drops *(Epifagus virginiana)*.

Because the area of interest lies within a floodplain, wetlands are a common climax community. Forested wetlands are consistent with MNFI's southern floodplain forest community. Dominant species of this community type include sugar maple, green ash *(Fraxinus pennsylvanica)*, red maple *(Acer rubrum)*, butternut *(Juglans cinerea)*, black maple *(Acer nigra)*, Ohio buckeye *(Aesculus glabra)*, box elder *(Acer nigundo)*, black ash *(Fraxinus nigra)*, black willow *(Salix nigra)*, and white poplar *(Populus deltoides)* (MNFI, 2003).

A review of National Wetlands Inventory maps identifies several classes of wetlands present within or near the Tittabawassee River floodplain, including emergent, forested, and scrub-shrub wetlands. Such communities have also been identified within the Shiawassee National Wildlife Refuge (USFWS, 2001).

The wildlife present within the Tittabawassee River floodplain is typical of that supported by the remaining natural forest and wetland communities. Despite the habitat fragmentation along the river, a diverse animal population is present. Resident game species include white-tail deer *(Odocoileus virginianus)*, ring-necked pheasant *(Phasianus colchicus)*, and wild turkey *(Meleagris gallopavo)*. Furbearers that are readily observed in the area include beaver *(Castor canadensis)*, muskrat *(Ondatra zibethica)*, mink *(Mustela vison)*, ground hog *(Marmota monax)*, and raccoon *(Procyon lotor)*. Birds include the belted king fisher *(Ceryle alcyon)*, great blue heron *(Ardea herodias)*, mallard duck *(Anas platyrhynchos)*, bank swallows *(Riparia riparia)*, American robin *(Turdus migratorius)*, great horned owl *(Bubo virginianus),* least sandpiper *(Calidris minutilla)*, blue jay *(Cyanocitta cristata),* red tail hawk *(Buteo jamaicensis)*, turkey vulture *(Cathartes aura)*, red-headed woodpecker *(Melanerpes erythrocephalus)* and Baltimore oriole *(Icterus galbula)* (Peters, 2001). The Shiawassee National Wildlife Refuge reports that 237 bird species, 9 reptile species, 9 amphibian species, 36 fish species, and 27 mammal species can be observed at the refuge throughout the year (Peters, 2001). Creel surveys conducted by Michigan Department of Natural Resources (MDNR) from 1999 to 2002 indicated that 14 different species of fish were taken from the Tittabawassee River by anglers (USDHHS, 2005). Walleye is the most commonly harvested fish.

According to the MNFI, two species listed as threatened under the federal Endangered Species Act and one candidate species for listing might occur in proximity to the area. The bald eagle *(Haliaeetus leucocephalus)* is a federally threatened species that might inhabit areas of both Saginaw and Midland Counties. Bald eagles typically nest near coastal areas, rivers, or lakes. The prairie fringed orchid is also listed as a federally threatened species, occurring in bogs and wet prairies in Saginaw County. The eastern massasauga rattlesnake *(Sistrurus catenatus catenatus)* is federally listed as a candidate species. It can be found in bogs, wet meadows, and floodplain forests in Saginaw County (MNFI, 1999).

In addition to the species listed above, the MDNR has listed nine animal species and six plant species in Midland or Saginaw counties as endangered or threatened under state law. The presence of appropriate habitat for these species within the Tittabawassee River and Floodplain study area has not been demonstrated. The animal species include the red-shouldered hawk *(Buteo lineatus)*, common loon *(Gavia immer)*, common tern (*Sterna hirundo),* king rail *(Rallus elegans)*, snuffbox mussel *(Epioblasma triquetra)*, spotted turtle *(Clemmys guttata)*, eastern fox snake *(elaphe vulpina gloydi)*, channel darter *(Percina copelandi)*, and river darter *(Percina shumardi)*. Listed plant species include three-awned grass *(Aristida longespica)*, sedge *(Carex seorsa)*, beak grass *(Diarrhena americana)*, showy orchis *(Galearis spectabilis)*, whorled pagonia *(Isotria verticillata)*, and hairy mountain-mint *(Pycnanthemum pilosum)* (MNFI, 1999). There are also 14 animal species and 8 plant species that have been listed as species of special concern by MDNR (MNFI, 1999).

3.2 AFFECTED MEDIA

This section provides a preliminary assessment of media in the Tittabawassee River and floodplain, based pooled data from studies conducted to date by Dow, its contractors, and MDEQ, as described in Section 2.2.

3.2.1 Distribution of Chlorinated Furans and Dioxins

Data used to perform a preliminary evaluation of the nature and extent of furans and dioxins in Tittabawassee River sediment and floodplain soil were obtained from previous investigations and the Scoping Study (CH2M Hill, 2005a). Sediment and floodplain soil data were compiled into a database and synthesized using a Geographic Information System (GIS) and other tools. Furan and dioxin data are presented in this section as World Health Organization (WHO) Toxicity Equivalency Quotient (TEQ) concentrations (TEQ). This means that 1998 WHO mammalian toxic equivalency factors (TEF) were applied in deriving estimates of TEQ, using the measured concentration of each furan and dioxin congener and then multiplying by the corresponding TEF. The individual TEQ products are summed to determine the sample TEQ concentration in 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) equivalents, as shown in the following equation:

*Total TEQ (2,3,7,8-TCDD equivalents) = Σ (Congener-specific concentration * Congener-specific TEF)*

3.2.1.1 Sediment

The sediment data available from studies conducted by MDEQ and Dow indicate that sediment TEQ concentrations are spatially variable, both horizontally and vertically. The median TEQ concentration in surface sediment over the length of the study area is 32 ppt; however, concentrations range from 0.58 ppt to 9,300 ppt. Previous investigations have reported that TEQ concentrations show no discernable pattern or trend with increasing distance from the Midland Plant.

Higher TEQ concentrations tend be found in surface sediment (0 to 0.3 ft), as compared with deeper subsurface sediment (greater than 0.3 ft). However, concentrations (greater than 1,000 ppt) exist at depth (that is, greater than 0.3 ft), and no clear pattern or trend in TEQ concentration with depth is apparent. Previous investigations report a high degree of vertical variability is generally found throughout the length of the study area and within individual cores.

3.2.1.2 Floodplain Soils

The median TEQ concentration in all relevant surface floodplain soil data available to date is 240 ppt, which is approximately an order of magnitude higher than the median concentration in Tittabawassee River sediment. Previous investigations report the TEQ concentrations appear to be less variable on a local scale than is the case for river sediments. In general, zones of higher and lower TEQ levels can be identified, and in some cases appear to show a trend of decreasing concentrations with distance from the river. No clear trends in floodplain soil furan and dioxin concentrations were found with increasing distance from the facility in studies to date.

As part of the evaluation of Scoping Study data, CH2M Hill performed statistical evaluations with the intent to assess potential relationships between surface floodplain soil TEQ concentrations and potential factors influencing the TEQ distribution. Their analysis showed that distribution of TEQ concentrations in the floodplain were most strongly predicted by two factors:

1. estimated distance from the river channel along flow paths predicted for an 8-year flood event (referred to as "streamline distance"), and

2. location of samples inside or outside of the 8-year Floodplain.

Both of these factors are strongly related to the processes that govern exchange of floodwaters and transport of solids between the river and floodplain. Streamline distance serves as a simplified surrogate for the complex suite of processes that govern erosion, transport, and deposition of solids in the floodplain, creating features such as natural levees and splays. The floodplain extent provides a natural limit to the area over which such transport can occur. For both of the factors described above, an 8-year flood event appeared to be a reasonable surrogate for the majority of the flooding events expected on the Tittabawassee River.

Other factors that were determined to have an influence on the predicted TEQ concentration in surface floodplain soil include TOC, grain size, and residence in a disturbed (cultivated) or undisturbed (forested) area. However, these factors were not found to be strong predictors when considered independently. The limited preliminary data available suggests that the vertical extent of furans and dioxins in floodplain soil decreases with increasing distance from the river channel. The observed trend is related to differences in accretion rate and other transport processes that may be occurring in the floodplain. This relationship will be further evaluated as part of the effort described in this SAP.

3.2.1.3 Other Media

Few surface water sample data are available for furans and dioxins in the Tittabawassee River. Floodwater samples were collected from three locations in the river between March 31 and April 7, 2005, to initially characterize total suspended solids and furan/dioxin concentrations (CH2M Hill, 2005b). These preliminary samples indicated a range of TEQ concentrations between 0.002 and 0.01 ppt, reported as TEQ per total mass of sample, including both water and solids. Dissolved-phase concentrations were not measured and are expected to be very low due to the hydrophobic nature of these compounds.

The potential presence of furans and dioxins in floodplain groundwater was investigated by MDEQ and the Saginaw County Health Department in 2003. MDEQ collected groundwater samples from 22 private water wells located adjacent to the estimated 100-year Floodplain as part of their Phase II Tittabawassee River/Saginaw River Dioxin Floodplain Sampling Study (MDEQ, 2003a). TEQ concentrations in the residential water well samples were all less than the Maximum Contaminant Level of 0.03 ppt, which again would be expected given the hydrophobic nature of furans and dioxins.

3.2.2 Other Contaminants

As part of the Baseline Chemical Characterization of Saginaw Bay Watershed Sediment (MDEQ, 2002b), MDEQ analyzed soil and sediment samples for a wide range of chemicals, including volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides and polychlorinated biphenyls (PCB), metals, and furans and dioxins. The findings from this study for chemical classes other than furans and dioxins were:

- VOCs: Except for one VOC positive (tetrachloroethylene) in a single sediment sample, VOCs were not found in floodplain soil samples. MDEQ concluded that the lack of detectable VOCs was expected because of the flow regime of the Tittabawassee River.

- SVOCs: The SVOCs MDEQ found in soils and sediments were principally polynuclear aromatic hydrocarbons (PAH). MDEQ characterized the concentrations of PAHs in sediment and floodplain soil samples as relatively low. Hexachlorobenzene was detected in one sediment sample in this study.

- Pesticides and PCBs: MDEQ did not detect PCBs in sediment or floodplain soil samples. They did, however, find the pesticide DDT present in some sediment and floodplain soil samples.

MDEQ noted that there had been a historical source of DDT on the Pine River (the former Michigan Chemical Company facility), and the DDT may have originated from that source.

- Metals: Most metals occur naturally in sediments and floodplain soils. MDEQ concluded that the levels of metals measured were generally consistent with background levels. Two floodplain sample locations were an exception to this, with some metals concentrations (arsenic, chromium, copper, lead, mercury, nickel, and zinc) elevated sufficiently to pose a potential for minor aquatic impacts. MDEQ also noted that these two locations were downstream of a former plate glass manufacturing facility known to have discharges metal-bearing wastewaters to the Tittabawassee River.

The Phase II Tittabawassee/Saginaw River Dioxin Floodplain Sampling Study conducted by MDEQ focused on furans and dioxins in sediments and soils (MDEQ, 2003a). This study indicated that certain furan congeners predominate in the furan-dioxin congener mixture of samples collected within the estimated 100-year Floodplain downstream of Midland, whereas dioxins predominate in the congener mixture upstream of Midland and outside of the estimated 100-year Floodplain. Along with furans and dioxins, PCBs were detected in floodplain soil samples, and less frequently in sediment samples. Although some PCBs were found soils and sediments, MDEQ has concluded that PCBs contribute very little to "dioxin-like" activity these soils and sediments (MDEQ, 2003a).

3.3 HISTORICAL PLANT OPERATIONS AND WASTE MANAGEMENT PRACTICES

The Midland Plant began operations in 1897 as The Dow Chemical Company. Expansion in production operations during the past century resulted in growth of the Midland Plant from 25 to approximately 1,900 acres. The majority of the Midland Plant is located on the east side of the Tittabawassee River and south of the City of Midland. Some of the current waste management (tertiary treatment ponds) operations are located on the southwest side of the river. The plant location and layout are depicted in Attachment B, Figure 3. The following subsections summarize the historical operations and waste management practices of the Midland Plant.

3.3.1 Overview of Plant Manufacturing Operations

Initially, the Midland Plant operations involved extracting brine from groundwater pumped from production wells ranging in depth from 1,300 to 5,000 feet below ground surface. Since its beginning the site has produced over 1,000 different inorganic and organic chemicals (Agin et al., 1984). This included the manufacture of 24 chlorophenolic compounds since the 1930s (Agin et al., 1984)

3.3.1.1 Early History of Dow Chemical

In 1896, after an earlier attempt to construct and operate a chlorine cell in Midland had failed, H.H. Dow set up a small chlorine cell room and bleaching powder plant on some land leased from the Midland Chemical Company, which had been extracting bromine from local brine. Dow bought their de-brominated brine for his process. This original bleach plant was made of tar, wood, iron, glass, and concrete.

On May 18, 1897, the Dow Process Company reorganized as The Dow Chemical Company, to manufacture and sell bleach. The new chlorine plant began operation on November 25, 1897 with the chlorine cells devised by H.H. Dow. (He called the cells "decomposers.") The cells used waste brine from the bromine operations without purification. The electrolytic cells were housed in nine "cell houses" each 40-feet wide by 90-feet long. The slaked lime absorber was also 40-feet wide but 368-feet long. Production in 1897 was 9 tons of bleaching powder per day, increasing to 72 tons per day in 1902 (20,000 tons/year). The cell had no diaphragm and did not make caustic, but was reported to have produced a gelatinous mass of iron, magnesium, and calcium hydroxides around the carbon cathode, which filled the cell in a week and required a shutdown for cleaning.

Another description of the original manufacturing process referred to Dow's chlorine "trap cell," which was constructed of tarred wood and contained electrodes made of arc-light carbon rods. Since Dow was not interested in producing caustic at this time, there was no need for a diaphragm except to prevent the hydrogen and chlorine from mixing and exploding. Dow inserted wooden troughs around each bank of carbon rods to trap the chlorine. The alkalinity that formed around the cathodic portions of the carbon rods was allowed to form a gelatinous precipitate of the hydroxides of iron, magnesium, and calcium on the surface of the carbon, which acted as a diaphragm. The chlorine was conducted from the cells in wooden pipes made of bored-out pine logs, cooled with water, and then passed over scrap zinc to dry it sufficiently to make good bleaching powder by reaction with lime. Eventually there were 16 cell buildings with 2 million carbon rods in service in 26,000 traps.

In 1899, the carbons of the new chlorine cell were treated by soaking in molten paraffin (135 ºF melting point) to plug pores for the purpose of preventing explosions. Dow researchers also are reported to have found that the tarred pine boards holding the carbons became "spongy" with exposure to the "corrosive chemicals" in the cells, and that replacing them "during the down-time" improved cell efficiency.

In 1902, H. H. Dow organized a new Midland Chemical Company differentiated from the original by being called Midland Chemical Company II, to develop a commercial synthesis for making chloroform and carbon tetrachloride, using sulfur chloride from Dow's Chlorine Cell operation. The building, on land leased from Dow Chemical, known as 3-B, made chloroform until 1942. The first sales of chloroform and carbon tetrachloride were made in 1903. Midland Chemical Company II was combined with The Dow Chemical Company in 1914.

In 1905, Dow began manufacture of benzoic acid by treating toluene with chlorine and then converting the resultant benzyl chloride into benzoic acid. This represented Dow's first venture into benzene ring chemistry.

In 1908, Dow manufactured two principal products, bromides and bleaching powder, and other small-volume products including mining salts, chemical insecticides and food preservatives, sulfur chloride, benzyl chloride and benzoic acid, carbon tetrachloride, and chloroform. In 1910 Dow had its first sales of lime sulfur (calcium sulfide) and lead arsenate sprays.

In 1911, Dow's scientists improved brine processing by developing a more sophisticated and efficient cell design than the old wooden chlorine cell. In the new plant, after the bromine [was] removed, the brine flowed into a vacuum evaporator, where steam heat and low pressure efficiently and rapidly boiled the brine and removed water. With evaporation, sodium chloride first precipitated and was removed. The liquid then passed into a second evaporator where magnesium chloride precipitated from the solution. The remaining viscous liquid was then transferred to a third evaporator, which removed the rest of the water, producing solid calcium chloride. Instead of two chemicals obtained from the brine, bromine and chlorine, the product number was increased to five, and the major ingredients of the brine were separated into useful products. [Previously,]…only bromine and chlorine were recovered, the rest of the components of the brine were discarded. (Karpiuk, 1984).

In 1913, Dow scientists further refined the chlorine-caustic soda electrolytic cell. These cells produced two useable products at the same time: chlorine and caustic soda. They used, as a feed, salt from the first stage vacuum evaporator that was re-dissolved in water. New vertical-filter-press cells were constructed of concrete and graphite rather than wooden frames and arc-light carbons. Dow "had elected to use 75 cells in a filter press series." Other producers had "adopted the unit cell," but Dow's bipolar cell achieved "electrical continuity…internally, with external connections to the rectifier circuit being made only at the anode and cathode terminals of a series which contains a multiplicity of cells." The cells are dubbed "bipolar" because "steel is the cathode and graphite is the anode in these cells."

In 1914, H. H. Dow abandoned his "trap cells" and announced the company would quit the manufacture of bleaching powder. He told associates the "real future of the Company lay in the use of its chlorine for products other than bleaching powder, especially chlorinated hydrocarbons." Dow produced its last bleach in July 1915. Demand was shifting from bleaching powder to chlorine, prompted by: chlorine's effectiveness in stemming typhoid outbreaks by direct injection into domestic water supplies; the blockade of German dyestuffs and organic intermediates; the liquefaction of chlorine and its transport in cylinders and tank cars; and the introduction of liquid chlorine into the manufacture of pulp and paper after World War I.

3.3.1.2 Manufacturing After Bleach

In 1915, in response to the British Navy's blockade of German exports and subsequent increased domestic demand, Dow began making phenol by the "sulfonation process." Phenol production during World War I was based on the benzene/sulfuric acid reaction and was used to produce trinitrophenol for artillery shells. Other wartime-introduced products included dichloroethylsulfide for mustard agent, monochlorobenzene for explosives, and hexachloroethane for smoke screens. In this time period Dow also began to produce aspirin, Epsom salts, other magnesium products, and some insecticides. Also in response to wartime demand, Dow began commercial production of magnesium metal produced by electrolysis of magnesium chloride.

In the mid-1930s, the Midland Plant began producing various chlorinated phenols, both directly for sale and for use as intermediates in the production of other chemicals (Agin et al., 1984). These chemicals were used primarily as fungicides, bactericides, or herbicides. Other products that began to be produced include styrene monomer, 1,1,1-trichloroethane, ethyl cellulose, vinyl chloride and vinylidene chloride.

In the 1940s, Dow added 2,4-D herbicide to its product line and over the decade expanded its production capability. In the 1940s and 1950s, the Midland Plant expanded manufacturing capacity of existing products and added products including ethanolamines, monochlorobenzene, phenol, Saran® resin, Styron® polystyrene, plastic and plastic lattices, soil fumigant, weed killers, ethylene dibromide, methyl styrene, polyvinyl chloride, styrene, trichlorophenol, parachlorophenol, and tetrachlorobenzene. In the 1950s, Dow began to manufacture STYROFOAM® brand plastic foam, Kuron® herbicide containing 2,4,5-trichlorophenoxypropionic acid, also known as Silvex.

In the 1960s and 1970s, the plant continued to expand both its production capacity and the number and range of products being manufactured, while ceasing to produce some products. There were plant expansions for ethyl benzene, styrene, bromine, bisphenol A, and polystyrene, and a new chloro-alkali plant was started up. The following are some examples of these new and expanded products and plants: crabgrass killer Zytron (DMPA or O-2,4-dichlorophenyl O-methyl isopropylphosphoramidothioate); a new form of pentachlorophenol with improved flow characteristics and shelf life; a new trichlophenol plant ; and a pilot plant for the production of Dursban™ insecticide (chlorpyrifos O, O- diethyl 0-(3,5,6-trichloro-2-pyridyl)l).

In the 1970s, full-scale production of the chlorpyrifos insecticides Dursban™ (household market) and Lorsban™ (agricultural market) [chlorpyrifos O,O-diethyl 0- (3,5,6-trichloro-2-pyridyl)l] began in Midland. Chlorine – caustic facilities in Midland were modernized. A new 2,4-D herbicide plant in Midland was built. The plant was to be designed for maximal recycling of all process water and by-products.

Chlorinated benzene production facilities in Midland were expanded and produced monochlorobenzene, ortho and paradichlorobenzene, trichlorobenzene, and tetrachlorobenzene. Midland stopped production of 1,2-dibromo-3-chloropropane, the active ingredient in Dow's Fumazone™ fumigant. Production of Ronnel™ fenchlorophos insecticide, an organophosphate insecticide (O,O-Dimethyl O-(2,4,5-trichlorophenyl) phosphorothioate) was also discontinued.

In the 1980s and 1990s, production began to decrease both in terms of capacity and range of products. The pentachlorophenol manufacturing plant at Midland, Michigan was closed down in October 1980. Also during this time the decision was made to shutdown the Midland chlorine/caustic soda plant. In the mid-1980s the Midland plant exited the brine business.

Currently the Midland Plant consists of approximately 30 production plants and a centralized Research & Development campus that serves Dow globally. Midland has been and remains a major research and development center for Dow. The research and development conducted is a mixture of pure research up to and including the construction of pilot plants, to test manufacturing processes prior to construction of manufacturing facilities at various Dow locations.

3.3.2 Overview of Plant Waste Management Practices

Waste management practices have evolved with the changing production and regulatory environment. Waste management practices at the Midland Plant have included onsite and offsite treatment and disposal of various waste products (MDEQ, 2003b). In the very early history of the Midland Plant, wastes were discharged directly to the Tittabawassee River and sometime later wastes were stored and treated in ponds. Other wastes were disposed of onsite either on the land or by burning (Agin et al., 1984). Over time, improvements in waste management practices included the installation and operation of a modern wastewater treatment plant as well as the use of incinerators instead of open burning. Improvements in the wastewater treatment plant and subsequent incorporation of pollution controls into both the operations of and emissions from the incinerators have reduced or eliminated releases and emissions from the Midland Plant.

Historic waste burning and waste incineration appear to be the primary source of elevated furans and dioxins found in surface soil in the Midland study area, as reported in "Point Sources and Environmental Levels of 2,3,7,8-TCDD (2,3,7,8–tetrachlorodibenzo-p-dioxin) on the Midland Plant Site of The Dow Chemical Company of Midland, Michigan," (November 5, 1984) ("1984 Report") (Agin et al., 1984). This study conducted by Dow was "a comprehensive search for all critical point sources of TCDD to the air, soil and water in the Midland area." The results of the study were submitted to federal, state, and local governmental agencies. This report contains details about historic manufacturing processes and waste management practices. The focus of this report is 2,3,7,8-TCDD. The study predated the discovery of significant concentrations of furans and dioxins in and along the Tittabawassee River, although the federal and state government was aware of 2,3,7,8-TCDD in fish, through their own studies and Dow studies, in the Tittabawassee and Saginaw Rivers.

Elevated furan levels in the Tittabawassee River and floodplain appear to be primarily attributable to historical manufacturing and related waste management practices at the Midland Plant. Prior to the 1920s, wastes from manufacturing processes were discharged directly to the Tittabawassee River. Beginning in the 1920s, aqueous waste typically was managed using pond systems and discharged to the river during high flow periods. Leaching from waste impoundments located near the river impacted the groundwater, which may have subsequently discharged to the river. In the 1930s, an early wastewater treatment plant was built and operated to treat phenolic wastes. In 1945, a general site wastewater treatment plant (WWTP) was constructed within the Midland Plant. Effluent from the WWTP did and currently discharges to the Tittabawassee River via an outfall. The wastewater treatment processes have undergone several upgrades over the years, including the construction of tertiary treatment ponds (referred to as "T-ponds") in 1974.

In the late 1970s, construction began on a 2.5-mile-long Revetment Groundwater Interceptor System (RGIS). The RGIS system was completed in 1992, when the T-Pond RGIS was finished. From 1994 to the present, upgrades and replacement work have taken place on the RGIS. A new tile system was constructed in 2002 along South Saginaw Road. The estimated length of all the tile systems is approximately 7 miles.

In 1984, sand filters were constructed to remove particulates from the tertiary effluent prior to discharge to the river. Operation of the T-ponds has been regulated by Dow's License since 1988. Historically, as many as 11 outfalls from the Midland Plant discharged to the Tittabawassee River (MDNR, 1972). Over time, the number of outfalls was reduced to a primary process wastewater outfall, with two emergency back up outfalls and several storm water outfalls.

4. CONCEPTUAL SITE MODEL

4.1 RIVER AND FLOODPLAIN MORPHOLOGY

The majority of the Tittabawassee River valley between Midland and Saginaw is characterized by relatively flat floodplains extending to sloping valley walls. The floodplains represent areas of the river valley that are periodically inundated by episodic flooding of the Tittabawassee River. The approximate extent of the 100-year Floodplain is shown in Attachment B, Figure 3. The upland areas above the river valley are typically 20 to 30 feet above the valley floor. As the river approaches the City of Saginaw, the valley in the vicinity of Center Road is characterized by gentler slopes away from the river and a broadening of the floodplain.

The river channel undergoes a change in sinuosity from upstream to downstream from the confluence of the Chippewa and Tittabawassee Rivers to the confluence of the Tittabawassee and Shiawassee Rivers.. The upper portion of the river is relatively straight, but sinuosity increases significantly as the river approaches Imerman Park.

The Tittabawassee River is a high-energy system that undergoes a rapid increase in flow in response to periods of precipitation, as indicated by a high ratio of the flood discharge to long-term average discharge. Analyses of in-river sediments indicate that they are composed of approximately 87 percent medium/fine sand. Areas of surficial fine-grained sediments (that is, silt or clay) that might be an indication of low-energy depositional areas were not encountered in poling and coring studies conducted in 2003 and 2004. This strong response to precipitation also results in overtopping of the riverbanks during larger flow events, and may contribute to ongoing erosion and deposition on and adjacent to the riverbanks under a range of flow rates.

4.2 LAND DEVELOPMENT

Residential, commercial, and industrial development in the Tittabawassee River floodplain is limited because of periodic flooding. Current land development within the estimated 100-year Floodplain was evaluated and assigned to one of seven categories similar to those used by the MDEQ for establishing generic cleanup criteria. Land development is summarized in Attachment D, Figures 1 through 18.

The dominant land development type in the estimated 100-year Floodplain is undeveloped/ recreational, which accounts for 57 percent of the total 100-year Floodplain area. Approximately three-quarters of the undeveloped/recreational land consists of undeveloped private property, with the remaining quarter consisting primarily of lands that are part of the Shiawassee National Wildlife Refuge and several small parks and boat launches. Agricultural lands are the next largest land development category and account for approximately 22 percent of the estimated 100-year Floodplain area. Agricultural areas are typically found in the lower elevation portions of the floodplain and are subject to regular flooding. Residential land development accounts for approximately 16 percent of the estimated 100-year Floodplain area. Residential structures are generally located at higher elevations in areas that are not routinely flooded.

4.3 POTENTIAL SOURCES

4.3.1 Potential Dow-Related Historical Contaminant Sources

4.3.1.1 Airborne Emissions

The historical waste management practices at the Midland Plant generated airborne contaminants in emissions from open burning and old style incinerator stacks, and in fugitive dust associated with uncovered stockpiles and construction activities. The 1984 Report provides a history of the incineration of liquid tars, and notes that incineration has been practiced at the Midland Plant since about 1930.

The primary source of furan and dioxin emissions to the atmosphere from the Midland Plant was incomplete combustion; either from waste materials containing furans and dioxins or of aromatic compounds that react with chlorinated organic compounds, chloride salts, and a metal catalyst (Agin et al., 1984). Production of chlorinated phenolic compounds has also been associated with the formation of furans and dioxins, principally with production of the higher chlorinated phenols (tri-, tetra-, and pentachlorophenols) (Agin et al., 1984). Other contaminants that could have been released though airborne emissions include VOC, SVOC, pesticides, PCB, and metals. It is not possible to discern which specific source affected which areas of the Midland study area. The 1984 Report concludes that, "Detailed analyses of past incineration practice, along with studies on the soils and airborne dust particles in the Midland area, show that historical dispersion of ashes and vent stack particulates from historical incineration operations are the probable source of the trace TCDD levels now found in the local environment."

4.3.1.2 Wastewater Discharges

As previously described, the primary source of furans and dioxins from the Midland Plant to the Tittabawassee River is believed to be historic releases of aqueous wastes. The original chlorine manufacturing processes, which operated in the first part of the 20th century, are believed to be the most likely source of the comparatively high furan TEQ readings in and along the river. The furans would have been discharged directly to the Tittabawassee River. At the time of the wastewater discharge from the bleach production facility there was no wastewater treatment or any ability to detect the presence of either furans or dioxins. Lesser amounts of dioxins in more recent sediments are believe to be related to chlorophenol production beginning in the mid-1930's. Over the many years of production at the Midland Plant, the wastewater discharges have changed in response to changes in the products and processes. Additionally, in that same time frame a number of activities have been undertaken specifically to reduce or eliminate releases of groundwater from beneath the Midland Plant which emerge at the Tittabawassee River, including closure of waste management units and outfalls, installation of the RGIS, and implementation of other release controls and monitoring programs as required by the License (MDEQ, 2003b).

On-site conditions and control of releases to the Tittabawassee River are being managed under the On-Site Corrective Action Program, and are not a part of this SAP. Current inspection and monitoring activities are intended to identify any source control failures before significant releases to the river occur. Given process improvements, closure activities, onsite corrective actions, and ongoing monitoring requirements, there do not appear to be significant ongoing sources of releases from the Midland Plant to the Tittabawassee River.

4.3.2 Potential Non-Dow-Related Historical Contaminant Sources

Many potential contaminants including VOCs, SVOCs, PCBs, metals, among others, are common contaminants associated with commercial and industrial activities, and cannot be attributed solely to operations at the Midland Plant. There are a significant number of commercial/industrial dischargers to the Tittabawassee River or its major tributaries. Current major point source dischargers to the river include the Midland Cogeneration Venture, the City of Midland WWTP, and the Saginaw Township WWTP. MDEQ water quality monitoring reports for tributaries upstream of Midland indicate that several WWTPs and various former industrial operations, including the Michigan Chemical Corporation, Velsicol Chemical Corporation, and Total Petroleum Inc., discharged to the Pine River. In addition, these same reports indicate a landfill, a WWTP and several industrial sites discharge to the Chippewa River. Therefore, it is likely that some contaminants in the Midland or Tittabawassee study areas may not be from the Midland Plant.

4.4 Fate and Transport

Because of the hydrophobic and highly sorptive nature of chlorinated furans and dioxins, movement of these compounds within a riverine setting is typically dominated by the transport and deposition of solids. Soil and sediment transport processes include in-channel solids transport through the water column as bedload and suspended sediment, erosion and deposition of solids in the banks and floodplain, and exchange between the river channel and floodplain under flood conditions. A summary of specific transport mechanisms that are relevant to the Tittabawassee River system and this SAP are presented below.

4.4.1 In-Channel Sediment and Transport of Chlorinated Furans and Dioxins

The Tittabawassee River receives solids from the Upper Tittabawassee, Pine, and Chippewa River watersheds upstream of the city of Midland. Under nonflooding conditions, these solids are transported primarily through the river channel as suspended material. These suspended solids may undergo some settling, deposition, and resuspension in the river channel, but suspended solids monitoring data collected to date suggest that the majority of suspended solids are simply conveyed through the Tittabawassee River and enter the Saginaw River at the confluence. In contrast, larger particles are typically transported via near-bed transport processes. The process by which larger particles (sand and gravel) move along the sediment bed by rolling, sliding, and hopping is generally referred to as bedload transport. Bedload materials typically travel for relatively short distances before redeposition, followed by resuspension and further downstream transport.

The degree to which furans and dioxins are transported in surface water in dissolved-phase or adsorbed to suspended solids is not well understood because of the limited surface water data set for furans and dioxins. Previous studies of the transport of other hydrophobic constituents such as PCBs suggest that the majority of furan and dioxin transport in the Tittabawassee River likely occurs via suspended solids, while bedload transport likely accounts for a small fraction of total transport (Jude et al., 1993).

The long-term behavior of the sediment bed in terms of its stability and role as a repository of furans and dioxins in the Tittabawassee is not fully understood at present. The occurrence of furans and dioxins at depth in the sediment bed suggests that mixing processes historically have been sufficient to move furans and dioxins below the surficial layer, but also that these mixing processes are occurring sufficiently slowly to allow the compounds to persist for some time once they make their way into the sediment bed. The sediment bed may also be affected by scour from winter ice formation and breakup. Ice-related factors that may affect the stability of the sediment bed include scour by individual ice floes, formation of ice jams, enhanced scour around or under ice jams, and overbank flooding.

4.4.2 Floodplain Erosion and Deposition

As part of the Scoping Study activities, CH2M Hill undertook field measurements of soil accretion using geochronology and dendrogeomorphology techniques. These methods produced estimated accretion rates ranging from 0.1-0.5 inches per year, with significant spatial variability. This observed net accretion is the product of years of erosion and deposition processes that may have varied significantly in time and space. The expected effect of such processes on particle-associated furan and dioxin transport is a combination of periodic deposition of new solids from the river, and ongoing redistribution and mixing of furans and dioxins from the floodplain. The generally positive net accretion observed in the floodplain to date suggests that deposition and burial is a dominant process in the floodplain, resulting in the floodplain acting as a net sink of solids and associated furans and dioxins over time. However, future changes in erosion and redeposition may influence the present-day furan and dioxin distribution over time.

Riverbanks are a separate area of ongoing erosion, as indicated by the undercutting and sloughing of bank materials observed at several locations along the river. Bank erosion may contribute to the ongoing transport of furans and dioxins because of the potential for migration of these chemicals from the floodplain to the river due to bank retreat. This may be important in areas of bank erosion (that is, "cut banks") that intersect former depositional areas such as natural levees.

4.4.3 River-Floodplain Exchange

Transport of solids between the river and floodplain (solids exchange) depends on the configuration of the river, local geomorphic features, and the amount of flow and solids transported during any given event. As described above, the Tittabawassee River channel at the north end of the study area is generally straighter, while the middle portion of the river is more sinuous. This is illustrated in the CH2M Hill Scoping Study Area 1 and Area 2. In both areas, transport of solids between the river and floodplain occurs as the river flow leaves the main channel during flood events. In both the upstream and downstream portions of the river, this river- floodplain interaction results in the transport of some river sediment into the floodplain, creating formations such as natural levees and splays.

The Scoping Study included an investigation of floodplain soil characteristics including organic content, particle size distributions, and associated furan and dioxin concentrations. Particle size distributions differ in the two areas. In Area 1, sandy materials predominate at most locations, with the exception of a line of more silty samples located on the inside of a shallow river bend. Higher TEQ concentrations appear to be associated with these silty samples, as well as with more sandy samples located in the natural levee area adjacent to the river. In Area 2, silty samples are more broadly distributed throughout the floodplain, and are generally associated with relatively high TEQ concentrations.

A comparison of the silty samples in both areas with estimates of their predicted streamline distances shows that most of these samples are at floodplain locations a short distance downstream from the river channel during flood conditions (that is, locations that have short streamline distances to the river under flood conditions). The observed gradient of relatively coarse sands in levee areas adjacent to the river and finer materials a short distance downstream in the floodplain is consistent with the sorting that would be expected during a flooding and sediment transport event. This suggests that transport of sediments from river to floodplain under flooding conditions may be a predictable phenomenon, and may also be a vector for historic and present-day transport of solids-associated furans and dioxins. The data available to date suggest that furans and dioxins may be preferentially associated with floodplain geomorphic features such as splays and levees that are formed by short-range sediment transport from river to floodplain. Elevated TEQ concentrations observed across broader areas of the floodplain may be related to deposition of finer-grained suspended sediment transported greater distances from the river channel during flood events.

The sediment transport observations described above were supported by the "influencing factor" evaluation performed in the Scoping Study, which showed that streamline distance was the strongest predictor of TEQ concentration in the floodplain. The streamline distance serves as a simplified surrogate for the complex suite of processes that result in the erosion and transport of a sediment particle, and its subsequent redeposition in the floodplain. In general, low streamline distance implies a strong transport link to sediments in the river, and a greater probability of transport and deposition of river sediments to a given location.

4.4.4 Other Fate and Transport Processes

The available evidence indicates that chlorinated furans and dioxins are stable compounds under most environmental conditions (ASTDR, 1998). Photo-oxidation and photolysis of nonsorbed species may be significant environmental transformation processes for furans and dioxins. Photolysis appears to be a relevant fate process in the top few millimeters of surface soil, where ultraviolet light penetrates. However, after these compounds are incorporated into the soil there are no significant losses through volatilization or photolysis. Photolysis also may occur in that portion of the water column where ultraviolet light penetrates. However, losses via this mechanism are generally thought to be insignificant.

Furans and dioxins are considered relatively resistant to microbial biodegradation in soil. Some studies suggest that furans and dioxins in sediments may undergo anaerobic reductive dechlorination, in the same manner as has been observed for PCBs. However, if reductive dechlorination of furans and dioxins occurs under natural anaerobic conditions the reaction rates are expected to be low based on structure activity relationships for similar organochlorine compounds.

4.5 EXPOSURE PATHWAYS AND RECEPTORS

Humans and ecological receptors may be exposed to hazardous substances in the Tittabawassee River and floodplain in a variety of ways. These pathways and potential effects from exposure to hazardous substances will be evaluated in the Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA).

5. FOCUSED INVESTIGATION APPROACH

This section provides the details of the *GeoMorph*™ SAP that are relevant to the detailed site characterization of the Upper Tittabawassee River. This section identifies the *GeoMorph*™ site characterization needs and presents a results-based approach for collecting the data to address those needs.

5.1 DATA REQUIREMENTS

Data needs associated with the *GeoMorph*™ SAP objectives are identified below. The approach presented in this section has been designed to address these data needs. Information collected during the implementation of the SAP will be integrated into the CSM outlined in Section 4 to prepare a refined the site model for the UTR that will be presented in the Site Characterization Report.

5.1.1 Primary and Secondary Constituents of Interest

The 17 chlorinated dibenzofurans and dibenzodioxins used to calculate TEQ are the primary Constituents of Interest (COI) in this investigation. Certain furan congeners dominate the furan-dioxin congener mixture in Tittabawassee River sediments and floodplain soils downstream of Midland, rendering them useful as analytical indicators of impact. Most of the TEQ of this mixture is attributable to these furan congeners. Because of the environmental fate and effects of these compounds, and their relatively low thresholds for environmental concern, it is likely that they will drive the ecologic and human health risk assessments.

However, because of the long and complex history of the Midland Plant as a manufacturer of chemicals, and the likelihood of other potential contributors of chemicals to the Tittabawassee River watershed, other PCOI are being evaluated in a collaborative effort by Dow, ATS, MDEQ and USEPA. A number of metals, chlorinated pesticides, and polynuclear aromatic hydrocarbons have already been added to the Target Analyte List (TAL) as secondary COI for this study. Secondary COI will be analyzed at a lesser frequency than furans and dioxins, on samples that are selected by Dow, ATS and MDEQ. The evaluation of PCOI will be completed and summarized in a Technical Memorandum to be submitted to MDEQ during the month of July, 2006. This Technical Memorandum will identify the compounds in the Near Plant TAL and the Downstream TAL, which will in turn be included in the 2006 Quality Assurance Project Plan (QAPP). The evaluation of the TAL will be included as Attachment F.

5.1.2 Constituents of Interest - Release History

Contaminant release histories constitute an important layer in the *GeoMorph*™ investigation process. The potential periods of release for furans and dioxins from the Midland Plant have been established, as discussed in section 3.3 above. Release histories for other potential or actual sources of constituents on the TAL will be established during the course of this investigation. Timelines will be prepared summarizing the relevant release history, and will be included in the Site Characterization Report.

5.1.3 Sediment Geochemistry

Once released to the aquatic environment, chlorinated furans and dioxins, like other environmentally persistent, hydrophobic organic chemicals, would be expected to bind preferentially to sediment particles and, in riverine settings, move with those particles through natural erosion/transport/deposition processes. The capacity to bind such chemicals is largely proportional to surface area of the particles, and the binding energy is largely dictated by the surface chemistry. As a result, these hydrophobic chemicals are most often found where fine grained sediments occur, and preferentially when those particles are composed with a significant carbon content (e.g. organic silts). In this way, it was originally expected that the furans and dioxins in the Tittabawassee River would be found where deposition of fine-grained sediments occurs. However, previous investigations have reported that these furans and/or dioxins occur in unexpected sediment deposits, including those that are predominantly medium or coarse grained (CH2M Hill, 2005c).

Understanding the occurrence of furans and dioxins is fundamental to this *GeoMorph*™ investigation. Therefore, to resolve this seemingly surprising finding of furans and dioxins where they would not be expected, a Geochemistry Study will be conducted concurrently with the field survey to evaluate where, precisely, the chlorinated furans and dioxins occur in Tittabawassee River sediment fractions. Selected samples from the *GeoMorph*™site characterization sampling will be analyzed for particle size distribution, particle density, and carbon content (organic, and graphitic or "black" carbon). Complete furan and dioxin analysis will be conducted on each isolated fraction using USEPA 1613B. Individual congener concentrations and TEQ values will be reported for each of the 17 furan and dioxin compounds.

To properly scope the analytical procedures for the Geochemistry Study, a Phase I Protocol was developed to evaluate the ability to fractionate soil samples and to establish the distribution of furans and dioxins in the various soil fractions from the Tittabawassee River floodplain. The evaluation will include the analysis of two archived soil samples from the Tittabawassee floodplain containing elevated levels of furans and dioxins. The soil samples will be fractionated into different size fractions, (i.e., sand, silt and clay, according to standard methods of soil analysis) (Day, 1965) and the distribution of furans and dioxins in each fraction will be determined. The correlation between the distribution of furans and dioxins and the organic carbon (e.g., total organic carbon and black carbon) of each fraction will be elucidated. The findings of the Phase I protocol evaluation will be reviewed and submitted to MDEQ in July, 2006. The final protocol for the Geochemistry Study is presented in Attachment G.

The Geochemistry Study protocol will be used to characterize a series of representative soil samples from the Tittabawassee floodplain during the implementation of the *GeoMorph*™ SAP. The exact location and number of soil samples will be identified and reviewed with MDEQ during the implementation of the SAP. In general, sample locations will be representative of mapped geomorphic features, targeting four depositional features per selected reach(es) and collecting four samples per feature. The results of the Geochemistry Study will be reported prior to issuing the *GeoMorph*™ Site Characterization Report, so that the findings can be taken into account in the analysis of the contaminant distribution, transport and fate.

5.2 FOCUSED INVESTIGATION APPROACH

5.2.1 Iterative Investigation Process

A fundamental element of the *GeoMorph*™ site investigation approach is that sampling activities are guided by near-real-time (NRT) feedback from the laboratory analyses. By having high quality data flowing back to the *GeoMorph*™ Project Team on a NRT basis, sampling locations and depths can be adjusted or "iterated in the field" to assure that an adequate number of representative samples are collected and the nature and extent of TAs are understood before sampling crews demobilize from a study area. A series of statistical tools are integrated into the iterative process to aid decision making related to the adequacy of geomorphic feature and site characterization. The statistical tools are outlined in Section 5.4.2 and a Technical Memorandum describing the statistical approach is presented in Attachment H. The iterative process for the *GeoMorph*™ site characterization is outlined in Attachment I and will be used throughout the implementation of the *GeoMorph*™ SAP.

5.2.2 Geomorphological Characterization

This SAP provides the sampling strategy, sampling locations, and procedures to determine the horizontal and vertical extent of TA contamination. The depositional environments in UTR have been mapped and a sampling strategy has been developed to determine the concentration and extent of TA contaminated sediment.

The purpose of the geomorphologic characterization is to determine the sediment depositional environments within the river channel, floodplains, and terraces of the Tittabawassee River and understand the storage and transport of TA contaminated sediments and soils. This characterization is important to understand the history of the geomorphology of the river in particular as it relates to contaminated sediment deposition patterns in the last 100 years. Geomorphological characterization includes defining parameters that influence river system dynamics. The parameters include channel gradient, width, depth, sinuosity, bed material, discharge, water velocity, sediment load, and sediment size.

The Tittabawassee River is a river that has moved laterally and incised since glacial times. The upland scarp is the glacial Tittabawassee River channel banks. The river has been relatively stable in its current channel since 1937, the time of the first aerial photographs of the river. The lateral movement in the upper 6 miles from the confluence with the Chippewa River is minimal, a maximum of 25 feet. There are locations where sediment deposition and erosion has occurred since 1937.

Anthropogenic influences on the watershed affect river system dynamics, resulting in watershed modifications and adjustments to system parameter values. The anthropogenic influences not only provide the source of contaminated sediment but also have changed the dynamics of the river by changing the flow regime and the resultant erosion and deposition pattern. The anthropogenic influences on the Tittabawassee River in the last 100 years include the following: development of the City of Midland; Dow Chemical; storm water and wastewater discharges; Sanford Dam water releases; the construction of the Dow Dam; bridge construction; sheet pile, rip-rap, berm and pond construction; and the Dow groundwater collection and treatment system. Each has had a pronounced affect on the flow regime and the erosion and deposition pattern of the Tittabawassee River. The geomorphological characterization of in-channel and overbank deposits is a multi-step process incorporating the results of the following investigation activities:

5.2.2.1 Topographic Mapping and Longitudinal Profile

The purpose of the detailed topographic mapping is to establish the longitudinal profile and sub-reaches of the river, compare the historic aerial photography to the present river configuration, and complete a preliminary mapping of the overbank floodplain and terraces. The purpose of the longitudinal profile is to determine changes in the channel gradient along the length of the river. The changes in the channel gradient have an affect on the sediment deposition pattern in the river channel. The channel gradient can also affect the overbank sediment deposition pattern.

5.2.2.2 Determination of River Reaches

The changes in the channel gradient provide information about the reaches of the river. The channel gradient, channel width, channel bed material, and sinuosity are used to determine the reaches of the river. A reach of the river is defined as an area of the river with a similar channel slope, channel width, channel bed material, and sinuosity. The reaches are important because the deposition pattern on like-geomorphic features will be similar within a reach.

5.2.2.3 Aerial Photograph Review

The historical aerial photograph review is conducted to determine the changes in the river, both man made and natural that affects the amount of lateral movement of the river over the time period of the contaminant release. This historical perspective provides information about the changes in the deposition and erosion pattern of the river. This information is used to focus the sampling investigation on the areas of historic sediment deposition for the time period of the contaminant release.

One of the first steps in the preparation of this SAP was to evaluate the aerial photo history of the Tittabawassee River from the confluence of the Chippewa River to the confluence of the Shiawassee River, and determine the availability and suitability of aerial photo coverage over the period of interest. Aerial photograph interpretation and geomorphic feature comparison at different points in time is a basic element, or "layer," of the *GeoMorph*™ process and contributes to the "lines of evidence" evaluation. Aerial photographs reveal changes in river channel location along with the progressive development of natural and anthropogenic features. Aerial photographs have also been used along the Tittabawassee River to capture flooding events for use in calibration of storm frequency, river stage and floodplain extent.

A search for historical aerial photographs along the Tittabawassee River reveals a rich history of information. In 2004, Dow conducted a detailed review of available aerial photography. The aerial maps were placed in the GIS system digitized versions of selected historical and recent aerial photography, along with historical USGS quadrangle maps, property boundary and zoning maps, soil characterization maps, and floodplain borders for various magnitude flood events. The GIS software employed is ESRI™ ArcMap™ ArcGIS 8.3™, which is a part of ArcView 8.3, a standard system regularly used by governmental units. All of the data within the GIS has been converted to the Michigan State Plane South (International feet) projection. All aerial photographic information entered into the GIS has been, or will be, ortho-rectified to correct for terrain distortion.

To supplement and confirm earlier work, ATS has conducted additional searches of available historical aerial photographs and topography, and has generated a long list of available historical resources. This search work conducted during the preparation of this SAP has included:

- A search of available historical private and color topography mapping dating back to the early 1900's by Environmental Data Resources, Inc. (EDR, 2006);
- A search of historical aerial photographs, in black and white, color and infrared from 1937 to 1993 (Intrasearch, Inc, 2006);
- A review of historical aerial photographs in the Dow Archives;
- Visits to the planning departments of Midland and Saginaw Counties and the City of Midland, and to the Natural Resource Conservation Service offices in both counties;
- A search of available historical aerial photos in the Michigan State University (MSU) Aerial Archives.

From these combined sources, ATS has selected the following shortlist of good quality aerial photographs that have complete coverage of the Tittabawassee River study area: 1937-1938, 1950, 1958, 1972, 1976, 1980-1982, 1986, 1998, and 2004. In addition to aerial photographs, early USGS topographic quadrangle maps were previously entered into the GIS for Saginaw County (1919, 1939, and 1941), and St. Charles County (1917, 1943 and 1950). These aerial photo sets and USGS quadrangle maps are either in hand as of this writing or have been ordered for use during the 2006 *GeoMorph*™ investigation. This series of photographs will provide "snapshots" of the Tittabawassee River at roughly 10 year intervals for interpretation and comparative evaluation of river channel locations, geomorphic features, and a variety of natural and anthropogenic features. Previous experience has demonstrated that a 10 year interval is optimal for determination of historical meanders and lateral movement of the river channel. During the 2006 Phase I *GeoMorph*™ investigation, ATS will select the most informative aerial photographs from this shortlist for digitizing, ortho-rectification, and entry into the GIS. The river channel will be digitized from the aerial photos for each of the chosen years. A graphical overlay of the various river channel locations over time will be generated and will aid in assessment of historical deposition areas and lateral movement trends.

The 1937-1938 series of aerial photographs along the Tittabawassee River represent the earliest aerial photo coverage of the study area. As an element of the work planning effort during the preparation of this SAP, the 1937-1938 river channel alignment was derived using ArcGIS from a digitally ortho-rectified version of the 1937-1938 aerial photography stored in the GIS data base. This 1937-1938 alignment was then digitally superimposed on the 2004 aerial photography and is presented in Attachment C, Figures 1 through 18. The information derived from this overlay was used to make an initial assessment of the lateral movement of the river channel over this 67 year period at selected transects and for the selection of the sediment and soils sampling locations presented in Section 5.3. This initial river channel comparison overlay was presented to MDEQ during the working sessions in May 2006 and will be included, among others, in the *GeoMorph*™ Site Characterization Report.

To support the initial *GeoMorph*™ sample location planning presented in this SAP, a combined digital file of the 2003 LiDAR topography mapping and bathymetry from the April 2004 LTI channel poling study, including contours derived from the combined digital file, was superimposed on the 2004 aerial photography to generate the base maps used in the April 2006 field verification and mapping of geomorphic features. These maps were also used as the base mapping for the geomorphic features and proposed sampling location maps presented in Section 5.3.

ATS commissioned additional aerial photography of the Tittabawassee River and Upper Saginaw River study area in April 2006 to obtain the aerial photography necessary to develop 1-foot contour intervals and to supplement and extend the aerial photo history. The ground control surveys needed for developing additional photo stereogrammetric topography mapping are being conducted on an as-needed basis.

5.2.2.4 Geomorphic Feature Mapping

The preliminary geomorphic feature mapping is conducted using the reaches of the river and the detailed topographic mapping to identify and map the geomorphic features of the river. The geomorphic features may include in-channel deposition areas, in-channel erosion areas, floodplain, low terraces, intermediate terraces, high terraces, and upland. For example, the deposition pattern will be similar on the low terraces within a reach of the river. The deposition pattern is confirmed by a detailed soil and sediment profile analysis that is conducted during the implementation of the SAP.

To clarify the setting for a soil and sediment description location, the terms *floodplain* and *terrace* (*low, intermediate, and high)* are used in a relative sense and are not based on flood elevation determinations. The soil and sediment profile descriptions are used to confirm or change the pre-field determination of floodplain or terrace (low, intermediate, or high) terminology. Although the terms are not based on flood stages, the use of the terms low terrace relates similar features, within a designated reach, based on topography and soil and sediment profile descriptions. The proximity of one geomorphic feature to another feature is also evaluated for selection of soil and sediment description locations. For example, an intermediate terrace adjacent to the river channel is considered a different geomorphic feature than an intermediate terrace separated from the river channel by a low terrace.

5.2.2.5 Soil and Sediment Profiling

In a river environment, it is important to relate one feature area to another when evaluating depositional environments. Soil profiles are described and compared to determine if features have been influenced by similar depositional and/or erosion factors. Soil description locations are selected based on their setting in the river environment. The selection of soil description locations is based on parameters that influence the geomorphic feature including the channel gradient, channel configuration (e.g., meander versus straight), elevation, potential for sediment deposition, and thalweg location.

The in-channel sediment is the most dynamic portion of the river system. The changes in water velocity, discharge, and sediment load and size due to seasonal and single event floods changes the erosion and deposition patterns of the in-channel sediments. Preliminary mapping and sampling of the in-channel sediments is necessary to obtain an understanding of the in-channel sediment conditions. However, detailed in-channel sediment mapping should occur as close to the desired corrective action as possible.

5.2.2.6 Geomorphic Polygons

Geomorphic polygons are graphic representation of individual geomorphic surfaces used in developing the geomorphic feature mapping. They are developed by applying knowledge of the river geomorphology together with detailed topographic information and mapping of in-channel sediments for channel and overbank areas. In some cases geomorphic features may have one or more geomorphic polygons based on the complexity of the depositional and erosional pattern. Similar geomorphic polygons can be established based on the relationship of the overbank features to the river channel, erosion and deposition areas for in-channel areas, and contaminant distribution. The preliminary geomorphic polygons for the UTR are presented in Attachment E, Figures 1 through 18.

Geomorphic polygons are confirmed based on measured deposition and erosion characteristics. After geomorphic polygons are confirmed, the applicable risk factors associated with the contaminant(s) can be applied to areas with similar deposition characteristics. The field verification process includes the following tasks.

- Soil Profile Description
- Sediment Profile Description

- TAL Analysis of Soil and Sediment Samples

5.2.2.7 Fate and Transport Considerations

A thorough understanding of the forces and processes responsible for the exchange of TA impacted solids in the river system is essential in the development of a scientifically sound remedial investigation. Additional information and data will be developed to properly characterize and model these processes to aid in the understanding of the movement and mobility of solids in the river system, to properly characterize erosion/deposition areas so that exposure risk can be properly evaluated, and to establish confidence about the predictability of the geomorphic model.

5.3 SAMPLE LOCATION DESCRIPTION

The following sections describe the Tittabawassee River sampling locations from the City of Midland Tridge at Reach A to Orr Road near the end of Reach O. Geomorphic characteristics, a summary of previous investigation(s), and a description of the proposed sampling locations are provided for each reach. The topographic surface, 2004 aerial photography, and sample locations for each reach are provided in Figures 1 through 18 of Attachment E.

Sample locations for each reach were selected based on both geomorphic feature and the overall channel setting. The geomorphic feature and the channel setting were considered for sample selection since fluvial transport and deposition are often correlated to these features.

Each defined geomorphic feature was represented by sample location(s) that can be described in terms of the factors used in the SWAC analysis. The channel setting categories that were used to group geomorphic feature sample locations include the following:

- Adjacent to channel
- Away from channel
- Straight channel segment
- Inside meander bend
- Outside meander bend
- Upstream or downstream of a bridge or culvert

The geomorphic features of the Tittabawassee River from the Midland City Tridge (Station 0+00) to near Orr Road (Station 320+00) were field mapped on April 18-21. The river was segmented from Reach A through Reach O and the relative geomorphic features from upstream to downstream were described using LiDAR map data and either direct field inspection, when property access was possible, or best possible visual observation.

Following are the geomorphic descriptive summaries for the reaches and the proposed sampling locations described by geomorphic feature and relationship to the river channel (adjacent or away). Attachment B, Figure 2 presents the locations of the reaches for the Upper Tittabawassee River, downstream from the City of Midland.

5.3.1 Reach A (Station 0+00 to 12+00)

Reach A extends from near the City of Midland Tridge at the confluence of the Chippewa and Tittabawassee Rivers at Station 0+00 to upstream from the Poseyville Road crossing at Station 12+00. Reach A is short compared to other reaches that were evaluated. The reach is straight with a flow direction predominantly towards the southeast (Attachment E, Figure 1).

The channel width of Reach A is relatively uniform throughout the reach and ranges from about 200 ft to 250 ft. The narrow channel reach segment of about 200 ft is associated with an old bridge structure that constricts the channel just upstream from the Reach A/B boundary. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which suggests a relatively gradual channel reach slope. The channel (bed slope, cross-section geometry) may be influenced by the downstream structure (dam) in Reach E.

There is some evidence of bank erosion and sediment deposition within floodplain areas, presumably from significant storm events. There is a rock wall erosion stabilization structure located upstream from the Reach A/B boundary along the northeast bank but no other identifiable bank stabilization structures within the reach. The reach is presumed to be relatively stable although it is influenced from significant storm/discharge events. The land use adjacent to the river in Reach A includes recreational land and residential/commercial development.

Low terrace is the predominant geomorphic feature adjacent to the channel reach banks. There are floodplain surfaces adjacent to both banks that that are limited in area. An intermediate terrace occurs on the northeast bank near the Reach A/B boundary.

Proposed Sample Locations

All proposed samples in Reach A are located in-channel. There are no overbank sample locations. The sample locations are included in two transects located perpendicular to the river. The transects are located at Stations 4+25 and 9+50.

Sample locations are defined in terms of proximity to channel (in-channel, away, and adjacent) and also geomorphic feature type for overbank samples. Only in-channel samples will be collected from the channel in Reach A.

<u>In-Channel</u>

Six in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample RA-4+25-IC-NE is an example of Reach A location nomenclature. The two transects for the in-channel sample locations are RA-4+25-IC and RA-9+50-IC.

5.3.2 Reach B (Station 12+00 to 37+50)

Reach B extends upstream from the Poseyville Road crossing at Station 12+00 to near Dow Facility Building #768 at Station 37+50. Reach B includes a gradual meander with an initial channel flow towards the southeast and a final channel flow towards the south (Attachment E, Figure 2).

The channel width of Reach B ranges from about 250 ft to 300 ft. The channel width is narrow upstream from the meander and increases downstream from the meander. A drainage channel on the southwest bank discharges into the reach near the mid-section of the meander at Station 29+50. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which suggests a relatively gradual channel reach slope. The channel (slope, cross-section geometry) may be influenced by the downstream structure (dam) in Reach E.

The northeast bank of the reach along the outside meander from Station 29+50 (drainage channel discharge) to Station 37+50 is protected with rip-rap. This portion of the channel bank, without protection, is subject to erosion because hydraulic energy associated with high river stage and discharge from the drainage way is contained within the river channel due to the uplands adjacent to the northeast bank.

The land use adjacent to the river in Reach B includes commercial and industrial facilities along the northeast and southwest bank of the upper reach. The land use along the lower portion of the southwest bank is associated with detention ponds and vegetated fields.

Low terrace and upland are the predominant geomorphic features adjacent to the channel banks. Low terrace and upland are common throughout the reach on the southwest and northeast bank, respectively. Floodplain of limited area occurs adjacent to both banks within the upper reach segment.

Proposed Sample Locations

A total of 18 in-channel and overbank samples are proposed to characterize in-channel, floodplain, and low terrace and upland locations. Two sample locations will be used to characterize the soil/sediment in a tributary to the river. The sample locations are included in four transects located perpendicular to the river. The transects are located at Stations 15+00, 22+00, 30+50, and 36+00.

Sample locations are defined in terms of proximity to channel (in-channel, away, and adjacent) and also geomorphic feature type for overbank samples. Samples will not be collected adjacent to the channel in Reach B.

In-Channel

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample RB-15+00-IC-NE is an example of Reach B location nomenclature. The four transects for the in-channel sample locations are RB-15+00-IC, RB-22+00-IC, RB-30+50-IC, and RB-36+00-IC.

Adjacent to Channel

- Floodplain: Floodplain is located on the southwest side of the river. A narrow band of floodplain extends from Station 30+00 to 32+00. One floodplain sample location is proposed at RB-30+50-SW5.

- Low Terrace: The low terrace is adjacent to the channel on both sides of the river. The northeast side is a remnant low terrace. This terrace is proposed to be sampled at RB-22+00-NE25. On the southwest side of the river at the downstream end of the reach one low terrace sample is proposed at RB-36+00-SW30.

Away from Channel

- Wetland: A large wetland complex is located upstream of the tributary to the river. One sample location at RB-30+50-SW905 is proposed to characterize this wetland area.

- Low Terrace: Low terrace is the predominant feature away from the river on the southwest side. One low terrace sample is proposed to characterize this feature, RB-30+50-SW85.

- Upland: The upland near the entrance to the Dow Industrial Facility is proposed to be characterized with one sample at RB-22+00-NE70.

Tributary

- A tributary enters the river from the southwest at Station 29+50. Two samples are proposed from the soil/sediment in this tributary; RB-29+50-T-SW180 and RB-29+50-T-SW705.

5.3.3 Reach C (Station 37+50 to 46+50)

Reach C extends from near Dow Facility Building #768 at Station 37+50 to near a Dow Facility wind sock along the northeast bank upstream from the F Street Bridge at Station 46+50. The length of Reach C is less as compared to other reaches that were evaluated. Reach C is straight with channel flow towards the south (Attachment E, Figure 3).

The channel width of Reach C is relatively uniform at about 280 ft to 300 ft. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The channel (slope, cross-section geometry) may be influenced by the downstream structure (dam) in Reach E. The northeast bank of the upper and lower segments of the reach is protected with rip-rap and sheet- pile revetment, respectively.

The land use adjacent to the river in Reach C includes commercial and industrial facilities along the northeast and southwest banks. There is a significant area on the southwest bank that includes detention pond(s) and fields with reed canary grass.

The predominant geomorphic features adjacent to the channel banks are low terrace and upland, although a narrow floodplain extends along the southwest bank. Upland occurs adjacent to the northeast bank and further away from the channel on the southwest bank.

Proposed Sample Locations

A total of ten in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, and low terrace locations. The sample locations are included in two transects located perpendicular to the river. The transects are located at Stations 38+50 and 45+00. Sample locations are defined in terms of proximity to channel (in-channel, away, and adjacent) and also geomorphic feature type for overbank samples.

<u>In-Channel</u>

Six in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample RC-38+50-IC-NE is an example of Reach C location nomenclature. The two transects for the in-channel sample locations are RC-38+50-IC and RC-45+00-IC.

<u>Adjacent to Channel</u>

- <u>Floodplain</u>: One sample location, RC-38+50-SW30 is proposed to characterize the floodplain in the upper reach on the southwest bank.

- <u>Low Terrace</u>: One sample location RC-45+00-SW20, is proposed to characterize the low terrace adjacent to the channel on the southwest bank.

<u>Away from Channel</u>

- <u>Low Terrace</u>: The low terrace is located along the southwest bank. Two samples are proposed to characterize the low terrace. One sample in the upper reach, RC-38+50-SW60, and one sample in the lower reach, RC-45+00-SW65.

5.3.4 Reach D (Station 46+50 to 59+25)

Reach D extends upstream from the F Street Bridge at Station 46+50 to upstream from the Dow Facility Dam. Reach D length is shorter by comparison to other reaches in the UTR. Reach D is straight with channel flow towards the south (Attachment E, Figure 4).

The channel width of Reach D ranges from about 250 ft to 450 ft. The channel width constricts at the F Street Bridge. The maximum channel width occurs upstream from the dam due to past modification (channel expansion) along the southwest bank. The hydraulic gradient of the channel reach, based on available LiDAR data, was greater than 0.005 ft/ft but less than 0.01 ft/ft, which is greater than most other reaches that were evaluated. The geomorphic features are often geometrically linear and vary in type and surface area throughout the reach. The channel (slope, cross-section geometry) is influenced by the downstream structure (dam) downstream from the Reach D/E boundary. The land use adjacent to the southwest bank includes industrial facilities, grassed fields, and detention ponds. The land use adjacent to the northeast bank is Dow industrial facilities.

The predominant geomorphic feature in the upper reach is upland. On the northeast bank downstream from the upper reach, the predominant feature is high terrace. On the southwest bank downstream from the upper reach, the predominant feature is high terrace except for a limited area that includes floodplain, low terrace, and intermediate terrace near the Reach D/E boundary.

Proposed Sample Locations

A total of eleven in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, low terrace, and intermediate terrace locations. The sample locations are included in three transects located perpendicular to the river. The transects are located at Stations 48+00, 55+00, and 56+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and also geomorphic feature type for overbank samples.

<u>In-Channel</u>

Seven in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample RD-48+00-IC-NE is an example of Reach D location nomenclature. The two transects for the in-channel sample locations are RD-48+00-IC and RD-55+00-IC.

<u>Adjacent to Channel</u>

- <u>Floodplain</u>: One sample location RD-56+00-SW10, is proposed in the floodplain on the southwest bank of the lower reach.

- <u>Low Terrace</u>: The low terrace is adjacent to the channel between the floodplain and the Dow dam control structure. One sample location RD-56+00-SW35, is proposed to characterize this terrace.

Away From Channel

- Low Terrace: One sample locations, RD-56+00-SW75, is proposed to characterize the low terrace on the southwest bank.

- Intermediate Terrace: One sample location RD-56+00-SW145, is proposed in the intermediate terrace on the southwest bank of the lower reach.

5.3.5 Reach E (Station 59+25 to 81+00)

Reach E extends upstream from the Dow Dam to downstream of the US Geological Survey gaging station (southwest bank) at Station 81+00. Reach E includes a gradual meander with an initial channel flow towards the south and a final channel flow towards the southeast (Attachment E, Figure 5).

The most significant structure in the reach is a concrete Dam located just downstream from the Reach D/E boundary. The Dam extends across the entire channel. The observed difference in stage across the Dam on April 18-19, 2006 was about 3-5 ft. The channel width of Reach E ranges from approximately 250 ft to 350 ft. The width is greatest upstream from the Dam and decreases downstream from the Dam. The hydraulic gradient of the channel reach downstream from the Dam, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The geomorphic features are often geometrically linear and vary in type and surface area throughout the reach.

Most of the northeast bank is protected with rip-rap. Upstream and downstream from the Dam sheet piling revetment and rip-rap protect the southwest bank from erosion. The erosion control structures extend about 700 ft downstream from the Dam on the southwest bank.

The land use adjacent to the southwest bank includes industrial facilities, grassed fields, and detention ponds. A large man-made lake greater than 40 acres is located several hundred feet from the channel. The land use adjacent to the northeast bank is Dow industrial facilities. Utility towers and power lines are common to the reach.

Geomorphic features include narrow bands of floodplain and low terrace adjacent to the southwest bank. Intermediate terrace is the predominant feature further from the southwest bank with pockets of upland. High terrace is the predominant feature further from the northeast bank.

Proposed Sample Locations

A total of thirty-two in-channel and overbank sample locations are proposed to characterize in-channel, natural levee, floodplain, low terrace, and intermediate terrace locations. The sample locations are included in six transects located perpendicular to the river. The transects are located at Stations 59+50, 61+50, 66+00, 69+50, 74+00, and 80+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and also geomorphic feature type for overbank samples.

In-Channel

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample RE-61+50-IC-NE is an example of Reach E location nomenclature. The four transects for the in-channel sample locations are RE-61+50-IC, RE-69+50-IC, RE-74+00-IC, and RE-80+00-IC.

Adjacent From Channel

- Floodplain: Three sample locations are proposed in floodplain on the southwest bank. The samples, RE-59+50-SW35, RE-66+00-SW10, and RE-69+50-SW20, are located on elongated narrow floodplain that occurs from the upstream to the central portion of the reach.

- Natural Levee: One sample, RE-80+00-SW20, is proposed to characterize the natural levee on the southwest bank of the lower reach.

- Low Terrace: One sample, RE-74+00-SW20, is proposed to characterize the low terrace on the southwest bank

Away From Channel

- Floodplain: One sample RE-59+50SW35, is proposed to characterize the floodplain on the upper reach of the southwest bank.

- Low Terrace: Two samples are proposed in low terrace on the southwest bank. The samples, RE-59+50-SW60 and RE-66+00-SW40, are on an elongated low terrace that is in the upper reach.

- Low/Intermediate Terrace: One sample, RE-80+00-SW50, is proposed in the low/intermediate terrace on the southwest bank of the lower reach.

- Intermediate Terrace: Eleven samples are proposed in intermediate terrace. Intermediate terrace occurs along most of the reach on the southwest bank. The intermediate terrace is narrow in the upper reach and expands downstream. Samples are proposed at five station/transect locations along the reach. The sample locations are:

RE-59+50-SW90	RE-66+00-SW65	RE-66+00-SW245
RE-66+00-SW430	RE-69+50-SW50	RE-69+50-SW250
RE-74+00-SW50	RE-74+00-SW180	RE-80+00-SW175
RE-80+00-SW270		

- High Terrace: One sample, RE-80+00-SW110, is proposed to characterize the high terrace on the southwest bank of the lower reach.

5.3.6 Reach F (Station 81+00 to 115+00)

Reach F extends downstream from the US Geological Survey gaging station (southwest bank) at Station 81+00 to downstream from the pipe crossing near Consumers Power Industrial Facility at Station 115+00. Reach F is straight with channel flow towards the southeast (Attachment E, Figure 6 and 7).

The channel width of Reach F ranges from about 200 ft to 250 ft. The minimum width is in the initial upper reach segment. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The geomorphic features are often geometrically linear and vary in type and surface area throughout the reach. Most of the northeast bank is protected with rip-rap. The southwest bank does not have erosion control structures.

The land use adjacent to the southwest bank includes industrial facilities, grassed fields, and detention ponds. A large man-made lake greater than 40 acres, also described in Reach E, is located several hundred feet from the channel. The land use adjacent to the northeast bank is Dow Industrial Facilities. A pipe structure crosses the river just upstream from the reach F/G boundary.

Geomorphic feature on the northeast side of the river is upland. The southwest bank is geomorphically complicated and includes several geomorphic features linearly oriented along the channel. The features include floodplain, low terrace, and intermediate terrace. Beyond the complex of the geomorphic features, upland is the predominant geomorphic feature.

Proposed Sample Locations

A total of 51 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levee, low terrace, intermediate terrace, and high terrace locations. The sample locations are included in eight transects located perpendicular to the river. The transects are located at Stations 82+00, 86+00, 90+50, 98+00, 103+50, 109+00, 112+50, and 115+00. Sample locations are defined in terms of proximity to the channel (away or adjacent) and also geomorphic feature type for overbank samples.

<u>In-Channel</u>

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample RF-86+00-IC-NE is an example of Reach F location nomenclature. The four transects for the in-channel sample locations are RF-86+00-IC, RF-90+50-IC, RF-103+50-IC, and RF-112+50-IC.

<u>Adjacent to Channel</u>

- <u>Natural Levee</u>: This levee is present on the southwest side of the river for the first 750 feet of the reach. A second area near the end of the reach is 300 feet long. This levee is proposed to be characterized by two sample locations, RF-82+00-SW25 and RF-112+50-SW15.

- <u>Floodplain</u>: The floodplain is present for the majority of the reach along the southwest bank. Four sample locations are proposed to characterize the floodplain.

  RF-90+50-SW10 RF-98+00-SW15 RF-109+00-SW5 RF-115+00-SW5

- <u>Low Terrace</u>: This terrace is present at one location adjacent to the southwest river bank, it is 100 feet long. The proposed sample location is RF-86+00-SW15.

<u>Away From Channel</u>

- <u>Natural Levee</u>: The natural levee is located on the southwest side of the river. The levee is located inland of the floodplain in this portion of the reach. This is indicative of lateral accretion occurring within the river banks. The longest levee is 1,150 feet long. Three samples are proposed to characterize this feature.

  RF-90+50-SW25 RF-98+00-SW30 RF-109+00-SW20

- Wetland: The wetland areas are present southwest of the river in the central to downstream portion of the reach. The wetlands are small and intermittent. Two sample locations will be used to characterize the wetlands; RF-98+00-SW50 and RF-103+50-SW150.

- Low Terrace: This terrace is the most extensive of the terraces on the southwest side of the river. This terrace extends the length of the reach. Eleven sample locations are proposed to characterize the low terrace.

RF-82+00-SW55	RF-90+50-SW45	RF-90+50-SW150	RF-98+00-SW80
RF-98+00-SW210	RF-103+50-SW90	RF-103+50-SW220	RF-109+00-SW30
RF-112+50-SW35	RF-115+00-SW50	RF-115+00-SW175	

- Low Intermediate Terrace: This terrace is located in the upstream portion of the reach. Five sample locations are proposed to characterize this terrace.

RF-82+00-SW50	RF-86+00-SW80	RF-86+00-SW260	RF-90+50-SW75
RF-90+50-SW220			

- Intermediate Terrace: The terrace is present on the southwest side of the river at the start of the reach and the end of the reach. Seven sample locations are proposed to characterize the intermediate terrace.

RF-82+00-SW185	RF-86+00-SW180	RF-86+00-SW320	RF-90+50-SW260
RF-109+00-SW35	RF-109+00-SW165	RF-112+50-SW110	

- High Terrace: The terrace is present in the upstream portion of the reach and the downstream central portion of the reach. Two sample locations, RF-82+00-SW120 and RF-103+50-SW20 are proposed to characterize this terrace.

- Upper High Terrace: This terrace is southwest of the river and abuts the berm. One sample location RF-109+00-SW195, is proposed to characterize this terrace.

5.3.7 Reach G (Station 115+00 to 141+00)

Reach G extends downstream from the pipe crossing near Consumers Power Industrial Facility at Station 115+00 to near the location of two gravel roads that extend from the Dow facility to the river at Station 141+00. Reach G meanders in the upper and lower segments resulting in flow towards the southeast in the upper segment, flow towards the northeast in most of the reach, and flow in the lower segment shifting towards the southeast (Attachment E, Figure 8).

The channel width of Reach G ranges from about 250 ft to 300 ft. The minimum width is near the midpoint of the reach in the location of the power plant discharge structure. A stream discharges into the river on the southwest bank of the upper reach segment. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The geomorphic features are often geometrically linear and vary in type and surface area throughout the reach.

Erosion control structures on the northeast bank include sheet pile revetment near the power plant discharge. Rip-rap is also located on the northeast bank on the outside meander near the lower reach segment. Erosion scars occur on the southwest bank of the lower reach segment. On the southwest bank, rip-rap is located along the banks of the river that discharges into the river. Rip-rap and a concrete wall are located on the southwest bank near and downstream from the power plant discharge. The land use on to the southwest bank includes Consumer Power Industrial Facilities, grassed fields, and woodland. Land use on the northeast bank is predominantly Dow Industrial Facilities.

Geomorphic features along the northeast bank include a linear complex of low terrace and floodplain. Features along the southwest bank include a complex of low terrace, intermediate terrace, and floodplain. Beyond the geomorphic features along the northeast and southwest banks, upland is the predominant geomorphic feature.

Proposed Sample Locations

A total of forty in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levee, low terrace, intermediate terrace, and high terrace locations. Two sample locations will be use to characterize the tributary channel to the river. The sample locations are included in five transects located perpendicular to the river. The transects are located at Stations 117+00, 122+00, 130+50, 135+50, and 140+00. Sample locations are defined in terms of proximity to the channel (away or adjacent) and also geomorphic feature type for overbank samples.

<u>In-Channel</u>

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. Sample

RG-117+00-IC-NE is an example of Reach G location nomenclature. The four transects for the in-channel sample locations are RG-117+00-IC, RG-130+50-IC, RG-135+50-IC, and RG-140+00-IC.

Adjacent to Channel

- Natural Levee: This levee is present on the northeast side of the river for 1,400 feet of the central portion of the reach. A second area near the end of the reach is 300 feet long. This levee is proposed to be characterized by two sample locations, RG-122+00-NE10 and RG-130+50-NE10.

- Floodplain: The floodplain is present at the beginning and end of the reach along the southwest bank. Two sample locations, RG-117+00-SW5 and RG-140+00-SW15, are proposed to characterize the floodplain.

- Low Terrace: This terrace is present at one location adjacent to the northeast side of the river and two locations on the southwest river bank. Three sample locations are proposed to characterize this low terrace.

  RG-122+00-SW25 RG-135+50-NE10 RG-135+50-SW30

- Intermediate Terrace: This terrace is present in the downstream central portion of the river. Two sample locations, RG-130+50-SW40 and RG-135+50-SW15, are proposed to characterize this terrace.

Away From Channel

- Floodplain: The floodplain is located on the northeast side of the river. The floodplain is located inland of the sheet pile and natural levee in this portion of the reach. The floodplain is proposed to be characterized with three sample locations.

  RG-122+00-NE70 RG-130+50-NE80 RG-135+50-NE30

- Wetland: The wetland areas are present southwest of the river in the downstream portion of the reach. Three sample locations are proposed to characterize the wetlands.

  RG-135+50-SW95 RG-135+50-SW270 RG-140+00-SW275

- Low Terrace: This terrace is present on both sides of the river. Five sample locations are proposed to characterize the low terrace.

RG-117+00-SW30 RG-122+00-NE45 RG-130+50-NE30 RG-140+00-SW70

RG-140+00-SW200

- Intermediate Terrace: This terrace is the most extensive of the terraces on the southwest side of the river extending from the start to the end of the reach. Seven sample locations are proposed to characterize the intermediate terrace.

  RG-117+00-SW90 RG-122+00-SW105 RG-130+50-SW185 RG-130+50-SW350

  RG-135+50-SW320 RG-135+50-SW630 RG-140+00-SW500

- High Terrace: The terrace is present in the upstream and central portion of the reach. One sample location, RG-117+00-SW185 is proposed to characterize this terrace.

Tributary

- Tributary: The tributary enters the river from the southwest at Station 116+00. Two samples are proposed from the soil/sediment in this tributary; RG-116+00-T-SW90 and RG-116+00-T-SW720.

5.3.8 Reach H (Station 141+00 to 163+50)

Reach H extends downstream from the location of two gravel roads that extend from the Dow facility to the river at Station 141+00 to the pipe crossing at Station 163+50. Reach H meanders in the middle segment resulting in flow towards the southeast in the upper segment, flow shifting toward the east in the middle segment, and flow in the lower segment shifting back towards the southeast (Attachment E, Figure 9).

The channel width of Reach H ranges from about 250 ft to 350 ft. The minimum width is near the upper reach boundary. The channel width increases near the mid-reach and the lower reach boundary. Discharge channels, associated with a large feature water impoundment away from the river, intersect the southwest bank at three locations. A channel also discharges into the river on the northeast bank near the lower reach boundary. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The geomorphic features adjacent to the channel are often geometrically linear and vary in type and surface area throughout the reach. Erosion control structures on the northeast bank include rip-rap in the upper reach. There are no erosion control structures on the southwest bank. Erosion scars occur on the southwest bank in the lower reach.

Land use on the northeast bank is predominantly Dow Industrial Facilities. The land use on to the southwest bank includes Consumer Power Industrial Facilities, surface water impoundment(s) of more than 100 acres, grassed fields, and woodland.

Geomorphic features along the northeast bank include a linear narrow band of floodplain and limited areas of low and intermediate terrace in the lower reach. Upland is the predominant geomorphic feature beyond the relatively long, steep slope which typically occurs less than 150 ft from the northeast channel bank. Features along the southwest bank include a narrow band of floodplain along the channel near mid-reach, areas of intermediate terrace away from the channel, and to a lesser extent low terrace. An extensive surface water impoundment is located about 600 ft to 800 ft away from the southwest bank.

Proposed Sample Locations

A total of 28 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Eight different geomorphic features are represented in Reach H. The sample locations are included in four transects located perpendicular to the river. The transects are located at Stations 142+00, 147+00, 158+00, and 162+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

<u>In-Channel</u>

Nine in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RH-147+00-IC-NE. The three transects for the in-channel sample locations are RH-147+00-IC, RH-158+00-IC, and RH-162+00-IC.

<u>Adjacent To Channel</u>

- <u>Natural Levee</u>: The natural levee is adjacent to the southwest side of the river at one location. The natural levee is 500 feet long starting at Station 144+00. One sample location is proposed to characterize the natural levee; RH-147+00-SW10.

- <u>Floodplain</u>: The floodplain is located on both sides of the river. On the northeast side of the river, the floodplain is at the end of the reach from Station 157+50 to 163+50 (600 feet long). The floodplain is more extensive on the southwest side of the river. The floodplain is continuous from the start of the reach to Station 154+00. This floodplain is 1,300 feet long. Three floodplain sample locations are proposed. The sample locations are:

RH-142+00-SW10 RH-142+00-SW85 RH-158+00-NE20

- Intermediate Terrace: The Intermediate Terrace is present on the southwest side of the river starting at Station 154+50 and extending 900 feet to the end of the reach. The intermediate terrace is associated with an erosion scar at two separate locations but the extent of the erosion is limited on this terrace. Two sample locations are proposed to characterize the terrace. The sample locations are:

RH-158+00-SW25 RH-162+00-SW25

Away From Channel

- Wetland: The wetland areas are low elevation areas away from the river. The wetland in Reach H is located on the southwest side of the river. The wetland is 350 feet long and starts at the beginning of the reach. The wetland is proposed to be characterized by one sample location; RH-142+00-SW240.

- Floodplain: At two locations the floodplain is separated from the river bank either by a natural levee (southwest) or as part of a tributary to the Tittabawassee River where it is separated from the river by an intermediate terrace (northeast). Two sample locations are proposed to characterize this floodplain away from the river channel.

RH-147+00-SW30 RH-162+00-NE165

- Low Terrace: The low terrace is located on both sides of the river. The northeast side low terrace is found in two separate areas near the downstream end of the reach. The larger of the two low terraces is 350 feet long. The southwest side low terrace is located in three areas with the largest located in the upstream portion of the reach. The largest of the low terraces is 550 feet long. The other two terraces are located in the central and downstream portion of the reach. Three sample locations are proposed to characterize the low terrace. The sample locations are:

RH-142+00-SW120 RH-158+00-NE70 RH-158+00-SW235

- Intermediate Terrace: The intermediate terrace is located on both sides of the river. The northeast side has one location in the downstream portion of the reach. The southwest side of the river has the terrace extending the length of the reach. Six sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RH-142+00-SW365	RH-142+00-SW665	RH-158+00-SW175	RH-158+00-SW365
RH-158+00-SW515	RH-162+00-NE30		

Adjacent To Channel

- Tributary: Four tributaries enter the river, three for the southwest at Stations 147+00, 155+00, and 162+50 and one from the northeast 161+50. Two samples are proposed to be collected from the soil/sediment in the 147+00 tributary; RH-147+00-T-SW40 and RH-147+00-T-SW200. One sample is proposed in the 155+00 tributary; RH-155+00-T-SW50. Two samples are proposed from the 161+50 tributary; RH-161+50-T-NE50 and RH-161+50-T-NE260.

5.3.9 Reach I (Station 163+50 to 185+50)

Reach I extends from the pipe crossing at Station 163+50 to downstream from a northeast bank concrete box at Station 185+50. Reach I meanders in the upper segment resulting in an initial flow direction towards the southeast and a final flow towards the south (Attachment E, Figure 10).

The channel width of Reach I ranges from about 250 ft to 400 ft. The maximum width is associated with the meander in the upper reach segment. A channel, associated with a more than 200 acre surface water impoundment away from the river, intersects the southwest bank in the upper segment. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The geomorphic features adjacent to the channel are often geometrically linear and vary in type and surface area throughout the reach. There are no erosion control structures on the banks of this reach. Erosion scars occur on the northeast bank in the outside meander bend.

Land use on the northeast bank is predominantly Dow Industrial Facilities. The land use on to the southwest bank includes Consumer Power Industrial Facilities, surface water impoundment(s) greater than 100 acres, grassed fields, and woodland.

Geomorphic features along the northeast bank include a linear narrow band of floodplain in the upper reach segment. A narrow band of low, intermediate, and high terrace occurs on the northeast bank near the Reach I/J boundary. Upland is the predominant geomorphic feature beyond the relatively long, steep slope which typically occurs less than 150 ft from the northeast channel bank. Features along the southwest bank include a narrow band of features adjacent to the channel including floodplain and low terrace. Further from the southwest bank, the predominant features are floodplain and intermediate terrace. An extensive surface water impoundment is located about 600 ft to 800 ft away from the southwest bank.

Proposed Sample Locations

A total of thirty-five in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Seven different geomorphic features are represented in Reach I. The sample locations are included in four transects located perpendicular to the river. The transects are located at Stations 167+50, 172+00, 177+50, and 184+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

<u>In-Channel</u>

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RI-177+50-IC-NE. The four transects for the in-channel sample locations are RI-167+50-IC, RI-172+00-IC, RI-177+50-IC and RI-184+00-IC.

<u>Adjacent To Channel</u>

- <u>Natural Levee</u>: The natural levee is adjacent to the southwest side of the river at one location. The natural levee is 250 feet long starting at Station 167+50. One sample location is proposed to characterize the natural levee; RH-167+50-SW10.

- <u>Floodplain</u>: The floodplain is located on both sides of the river. On the northeast side of the river, the floodplain is present at the start of the reach to Station 169+00 (550 feet long). The floodplain is more extensive on the southwest side of the river. The floodplain is continuous from Station 172+00 to the end of the reach. This floodplain is 1350 feet long. Three floodplain sample locations are proposed. The sample locations are:

  RI-167+50-NE10 RI-172+00-SW25 RI-184+00-SW10

- <u>Low Terrace</u>: The low terrace is adjacent to the river at two locations within the reach. The northeast low terrace is at the end of the reach. The terrace is 250 feet long. The southwest low terrace is immediately downstream of the mouth of a tributary channel. This terrace is 150 feet long. Two sample locations are proposed to characterize this terrace. The sample locations are:

RI-172+00-SW15   RI-184+00-NE10

- Intermediate Terrace: The Intermediate Terrace is present on both sides of the river. The northeast intermediate terrace is located in the downstream portion of the reach. The terrace is 400 feet long. The southwest terrace is located at the beginning of the reach and is 400 feet long. One sample location is proposed to characterize the terrace; RI-167+50-SW15.

Away From Channel

- Natural Levee: The natural levee is located on the southwest side of the river. The levee is located inland of the floodplain in this portion of the reach. This is indicative of lateral accretion on the inside of the meander bend. This levee is 1,350 feet long. One sample is proposed to characterize this feature; RI-184+00-SW30.

- Wetland: The wetland areas are low elevations areas away from the river. The wetland in Reach I is located on the southwest side of the river. The wetland is geographically extensive; 1950 feet long and 350 feet wide at its widest point. The wetland is characterized to be proposed by five sample locations. The sample locations are:

RI-167+50-SW325   RI-167+50-SW550   RI-172+00-SW500   RI-184+00-SW210
RI-184+00-SW420

- Low Terrace: The low terrace is located on the southwest side of the river. The southwest side low terrace is a continuous feature that parallels the floodplain and natural levee. The terrace is 1,350 feet long. One sample location is proposed to characterize the low terrace; RI-184+00-SW45

- Intermediate Terrace: The intermediate terrace is located on both sides of the river. The northeast side has one location in the downstream portion of the reach. The southwest side of the river has the terrace extending the length of the reach. Eight sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RI-167+50-SW110   RI-167+50-SW270   RI-167+50-SW710   RI-172+00-SW50
RI-172+00-SW290   RI-184+00-NE35   RI-184+00-SW70   RI-184+00-SW520

- High Terrace: The high terrace is located on both sides of the river. The northeast side of the river has one high terrace at the end of the reach. The terrace is 650 feet long. The high terrace on the southwest side of the river is bounded by berms and roads. One sample is proposed to characterize the high terrace; RI-184+00-NE75.

Tributary

- Tributary: A tributary enters the river from the southwest at Station 170+50. Two samples are proposed to characterize the soil/sediment RI-170+50-T-SW70 and RI-170+50-T-SW400.

5.3.10 Reach J (Station 185+50 to 196+50)

Reach J extends from a location downstream from a northeast bank concrete box at Station 185+50 to near a discharge channel on the southwest banks that is associated with a surface water impoundment at Station 196 +50. Reach J length is less as compared to other reaches that were evaluated. Reach J is straight with flow towards the south (Attachment E, Figure 11).

The channel width of Reach J ranges from about 250 ft to 300 ft. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.005 ft/ft which indicates a relatively gradual channel reach slope. The geomorphic features adjacent to the channel are often geometrically linear and vary in type and surface area throughout the reach.

There are no erosion control structures on the banks of this reach except that the banks of the drainage channel that intersect the southwest bank near the reach J/K boundary are protected with rip-rap. Erosion scars occur on the northeast bank for most of the reach.

Land use on the northeast bank is predominantly Dow Industrial Facilities, grassed fields, and woodland. The land use on to the southwest bank includes Consumer Power Industrial Facilities, surface water impoundment(s) greater than 100 acres, grassed fields, and woodland.

Geomorphic features along the northeast bank include a linear .band of low and intermediate terrace in the upper reach segment. The features in the lower reach segment include a limited floodplain area and a broad high terrace that transitions into upland near a relatively long, steep slope that is about 150 ft from the northeast channel bank. Features along the southwest bank include a small floodplain area in the upper reach segment. Features near the southwest bank include linear areas of intermediate and low terrace. Further from the southwest bank, floodplain areas are the most extensive feature. An extensive surface water impoundment is located about 400 ft away from the southwest bank.

Proposed Sample Locations

A total of 25 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. One sample location will be use to characterize the tributary from the southwest. Eight different geomorphic features are represented in Reach J. The sample locations are included in two transects located perpendicular to the river. The transects are located at Stations 187+50 and 192+50. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

<u>In-Channel</u>

Six in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RJ-187+50-IC-NE. The two transects for the in-channel sample are proposed RJ-187+50-IC and RJ-192+50-IC.

<u>Adjacent To Channel</u>

- <u>Natural Levee</u>: The natural levee is adjacent to the southwest side of the river at two locations. The combined natural levee is 450 feet long. The natural levee is associated with erosion scars. Two sample locations are proposed to characterize the natural levee. The sample locations are:

  RJ-187+50-SW20 RJ-192+50-SW15

- <u>Floodplain</u>: The floodplain is located on both sides of the river. On the northeast side of the river, the floodplain is at the end of the reach from Station 194+00 to 196+50 (250 feet long). The floodplain on the southwest side of the river is similar to the northeast in length but is located at the beginning of the reach. One floodplain sample is proposed; RJ-187+50-SW10.

- <u>Low Terrace</u>: The low terrace is present at the beginning of the reach on the northeast side of the river. This terrace is 150 feet long. This terrace is sampled in Reach I just upstream of the reach break. This terrace is not sampled as part of the Reach J sampling.

- <u>Intermediate Terrace</u>: The intermediate terrace is present on both sides of the river. The northeast terrace is 700 feet long. The southwest intermediate terrace is associated with an erosion scar at two separate locations. Three sample locations are proposed to characterize the terrace. The sample locations are:

RJ-187+50-NE15 RJ-192+50-NE15 RJ-192+50-SW25

Away From Channel

- Historic Natural Levee: The historic natural levee is located on northeast side of the river. This feature is 350 feet long located in the central portion of the reach. The feature is proposed to be characterized with one sample location; RJ-192+50-NE50.

- Wetland: The wetland areas are low elevations areas away from the river. The wetland in Reach J is located on the southwest side of the river. The wetland is 800 feet long and starts at the beginning of the reach. The wetland is proposed to be characterized by three sample locations. The sample locations are:

  RJ-187+50-SW165 RJ-187+50-SW365 RJ-192+50-SW150

- Low Terrace: The low terrace is located on both sides of the river. The northeast side low terrace is found adjacent to the floodplain at the downstream end of the reach. The terrace is 200 feet long. The southwest side low terrace is located in two areas with the largest located in the downstream portion of the reach. The largest of the low terraces is 300 feet long. One sample location is proposed to characterize the low terrace; RJ-192+50-SW80

- Intermediate Terrace: The intermediate terrace is located on both sides of the river. The northeast side has two locations, one in the upstream (150 feet long) and one in the downstream (250 feet long) portion of the reach. The southwest side of the river has the terrace extending the length of the reach. Five sample locations are proposed to characterize the intermediate terrace. The sample locations are:

  RJ-187+50-SW35 RJ-187+50-SW115 RJ-187+50-SW415 RJ-192+50-SW40
  RJ-192+50-SW290

- High Terrace: The high terrace is located on the northeast side of the river. The terrace extends the length of the reach. The high terrace is proposed to be characterized by three sample locations. The sample locations are:

  RJ-187+50-NE75 RJ-192+50-NE80 RJ-192+50-NE180

Tributary

- Tributary: A tributary enters the river from the southwest at Station 195+50. One sample is proposed to characterize the soil/sediment in this tributary: RJ-195+50-T-SW210.

5.3.11 Reach K (Station 196+50 to 233+50)

Reach K extends from a discharge channel on the southwest bank at Station 196+50 to near the Gordonville Road Bridge at Station 233+50. Reach K meanders near mid-reach resulting in flow towards the south in the upper segment and flow towards the southeast in the lower segment (Attachment E, Figure 12 and 13).

The channel width of Reach K ranges from about 175 ft to 325 ft. The minimum channel width is near mid-reach in the meander and the maximum width is near the upper and lower reach segments. There are four drainage channels along the southwest bank of the reach, one of which includes a concrete box culvert. Some or all of these drainages are associated with a large surface water impoundment on Consumer Power property. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.0001 ft/ft that indicates a gradual channel slope. The geomorphic features are often geometrically linear and vary in type and area throughout the reach.

The channel banks do not have erosion control structures. The land use adjacent to the river in Reach K is predominantly woodland.

The predominant geomorphic features on the northeast bank include low and intermediate terraces adjacent to the channel. A broad area of low terrace, high terrace, and floodplain occur away from the southwest bank channel followed by upland. The feature adjacent to the southwest bank is predominantly intermediate terrace followed by the high terrace and upper high terrace.

Proposed Sample Locations

A total of 95 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Five sample locations are proposed to characterize three tributaries entering the river. Fourteen different geomorphic features are represented in Reach K. The sample locations are included in eight transects located perpendicular to the river. The transects are located at Stations 197+00, 201+00, 206+00, 211+50, 216+50, 219+50, 224+50, and 232+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

In-Channel

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RK-246+00-IC-NE. The four transects for the in-channel sample locations are RK-197+00-IC, RK-206+00-IC, RK-216+50-IC, and RK-232+00-IC.

Adjacent To Channel

- Natural Levee: The natural levee is adjacent to the northeast side of the river. The levee is 1300 feet long starting at Station 209+50. The natural levee is associated with an erosion scar along the river bank. Three sample locations are proposed to characterize the natural levee. The sample locations are:

  RK-211+50-NE20 RK-216+50-NE20 RK-219+50-NE30

- Floodplain: The floodplain is located in three separate areas; two northeast and one southwest of the river. A floodplain is present northeast of the river at the beginning of the reach. This floodplain is 100 feet long. The other northeast floodplain is near the downstream end of the reach and is 900 feet long. The southwest floodplain is in the downstream portion of the reach and is 100 feet long. Two floodplain sample locations are proposed. The sample locations are:

  RK-197+00-NE5 RK-224+50-NE20

- Low Terrace: The low terrace is adjacent to the river at the beginning of the reach on the northeast side of the river. This terrace is 400 feet long and is located on the inside meander bend. The terrace is present on the southwest side of the river in the central portion of the reach. The terrace is 350 feet long. Two sample locations are proposed to characterize this terrace. The sample locations are:

  RK-201+00-NE10 RK-211+50-SW30

- Intermediate Terrace: The intermediate terrace is present in the upstream portion of the reach on the northeast side of the river. This terrace is 450 feet long. The intermediate terrace is present at three separate locations on the southwest side of the river. The longest and most upstream terrace is 1,150 feet long. One terrace is present in the central portion of the reach and is 800 feet long. The downstream terrace is 600 feet long and associated with an erosion scar. The other southwest intermediate terraces have minor areas along their length that have an erosion scar. Seven sample locations are proposed to characterize the terrace. The sample locations are:

RK-197+00-SW35	RK-201+00-NE60	RK-201+00-SW25	RK-206+00-NE35
RK-206+00-SW25	RK-219+50-SW40	RK-224+50-SW45	

- High Terrace: The high terrace is located on both sides of the river. The northeast side has a terrace 350 feet long just upstream of the central portion of the reach. The terrace on the southwest side of the river is located at the downstream end of the reach. The terrace is 300 feet long. Both terraces are associated with an erosion scar. Three sample locations are proposed to characterize the high terrace. The sample locations are:

RK-206+00-NE50	RK-232+00-NE40	RK-232+00-SW20

Away From Channel

- Natural Levee: The natural levee away from the channel is located on the northeast side of the river. The levee is located inland of the floodplain in this portion of the reach. This levee is 550 feet long. The feature is proposed to be characterized with one sample location; RK-224+50-NE35.

- Historic Natural Levee: The historic natural levee is present in three locations, two on the northeast and one on the southwest side of the river. The three levees occur on the downstream portion of the reach. The northeast levees are 900 feet and 450 feet long from upstream to downstream. The southwest levee is 800 feet long. The historic natural levee is proposed to be characterized with five sample locations. The locations are:

RK-216+50-NE70	RK-216+50-SW45	RK-219+50-NE70	RK-219+50-SW60
RK-224+50-NE85			

- Wetland: The wetland areas are low elevation areas away from the river. The wetland northeast of the river is 3,000 feet in length. This wetland is the dominant geomorphic feature on the northeast side of the river. The feature is proposed to be characterized by eight sample locations. The sample locations are:

RK-201+00-NE440	RK-206+00-NE515	RK-211+50-NE220	RK-211+50-NE555
RK-216+50-NE420	RK-219+50-NE135	RK-219+50-NE485	RK-224+50-NE330

- Low Terrace: The low terrace is located on both sides of the river. The northeast side low terrace is 2,950 feet long. This terrace is linear and encompasses the wetland except at the downstream end of the wetland. The southwest side low terrace is located between two tributary channels in the upstream portion of the reach. Fourteen sample locations are proposed to characterize the low terrace. The sample locations are:

RK-197+00-NE40	RK-197+00-NE420	RK-201+00-NE425	RK-201+00-NE580
RK-201+00-SW220	RK-201+00-SW345	RK-206+00-NE300	RK-206+00-NE665
RK-211+50-NE185	RK-211+50-NE645	RK-216+50-NE115	RK-216+50-NE605
RK-219+50-NE570	RK-224+50-NE160		

- Intermediate Terrace: The intermediate terrace is located on both sides of the river. The northeast side has two separate terraces; one in the upstream portion of the reach (500 feet long) and one near the end of the reach (800 feet long). The southwest side of the river has one terrace located in the central portion of the reach. This terrace is 350 feet long. Seven sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RK-197+00-NE25	RK-201+00-NE25	RK-206+00-SW75	RK-211+50-SW55
RK-224+50-NE30	RK-224+50-NE115	RK-232+00-SW75	

- High Terrace: The high terrace is located on both sides of the river. The northeast side of the river has two occurrences of the terrace; one in the upstream and central portion of the reach and one at the end of the reach. The high terrace in the upstream and central portion of the river is 2150 feet long. The terrace is geographically extensive in the upstream portion of the reach.

  The high terrace on the southwest side of the river extends the entire length of the reach except for a 200 foot gap between two tributary channels. This terrace is linear in nature and is approximately 550 feet wide at its widest point. Twenty-one sample locations are proposed to characterize the high terrace. The sample locations are:

RK-197+00-NE70	RK-197+00-NE325	RK-197+00-SW265	RK-201+00-NE65
RK-201+00-SW145	RK-201+00-SW370	RK-206+00-NE170	RK-206+00-SW120
RK-206+00-SW360	RK-211+50-NE45	RK-211+50-SW80	RK-211+50-SW260
RK-216+50-NE35	RK-216+50-NE185	RK-216+50-SW75	RK-216+50-SW370
RK-219+50-SW100	RK-224+50-SW90	RK-224+50-SW305	RK-232+00-NE190
RK-232+00-SW205			

- Upper High Terrace: The upper high terrace is higher in elevation than the high terrace, geographically extensive, and located on the southwest side of the river. The terrace starts at 202+00 and extends to the end of the reach. The width of this terrace varies from 25 feet to 1,400 feet. Eight sample locations are proposed to characterize the upper high terrace. The sample locations are:

  RK-206+00-SW425 RK-206+00-SW690 RK-211+50-SW480 RK-211+50-SW785
  RK-216+50-SW440 RK-216+50-SW885 RK-219+50-SW390 RK-224+50-SW700

- Upland: The upland area present in this reach is at the borders of the geomorphic features and is typically a steep scarp to a flat upland area. The upland on the northeast side of the river has a flatter gradient than is typically the case. These areas will be sampled to determine if the upland has been impacted by floodwater. This upland is proposed to be characterized with two sample locations. The sample locations are:

  RK-197+00-NE545 RK-211+50-NE710

Tributary

- Tributary: Three tributaries enter the river from the southwest at Stations 199+00, 212+00, and 225+00. Two samples are proposed from the soil/sediment in the 199+00 tributary; RK-199+00-T-SW60 and RK-201+00-T-SW360. One sample is proposed from the soil/sediment in the 212+00 tributary; RK-212+00-T-SW40. Two samples are proposed from the 225+00 tributary; RK-225+00-T-SW75 and RK-225+00-T-SW340.

5.3.12 Reach L (Station 233+50 to 261+50)

Reach L extends from near the Gordonville Road Bridge at Station 233+50 to the Smith Crossing Bridge at Station 261+50. Reach L meanders very gradually towards the southeast which is also the overall reach flow direction (Attachment E, Figure 14).

The channel width of Reach L ranges from about 250 ft to 300 ft. The maximum channel width is upstream from the Gordonville Road Bridge. There are also drainage channels on both banks upstream from the Gordonville Road Bridge that discharge into the river. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.0001 ft/ft which indicates a gradual channel slope. The geomorphic features are often geometrically linear and vary in type and surface area throughout the reach.

Erosion scars occur on both the northeast and southwest banks along most of the reach. The channel banks do not have erosion control structures. The land use adjacent to the river in Reach L is predominantly woodland.

The predominant geomorphic features adjacent to the northeast bank include a relatively narrow band of low terrace, floodplain, and a limited area of intermediate terrace near the Gordonville Road Bridge. Further from the northeast channel bank there is a broad area of high terrace and upper high terrace. The predominant features on the southwest bank adjacent to the channel include a narrow band of intermediate and high terrace. Further from the southwest bank is a broad area of low terrace and floodplain followed by upper high terrace and upland.

Proposed Sample Locations

A total of 79 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Four samples locations are proposed to characterize the tributaries that enter the river at the downstream end of the reach. Eleven different geomorphic features are represented in Reach L. The sample locations are included in five transects located perpendicular to the river. The transects are located at Stations 235+50, 239+00, 246+00, 252+00, and 258+50. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

<u>In-Channel</u>

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RL-246+00-IC-NE. The four transects for the in-channel sample locations are proposed RL-239+00-IC, RL-246+00-IC, RL-252+00-IC, and RL-258+50-IC.

<u>Adjacent To Channel</u>

- <u>Natural Levee</u>: The natural levee is adjacent to the northeast side of the river at two separate locations. The upstream levee is 350 feet long starting at 236+00. The downstream levee is 550 feet long starting at 249+00. The upstream natural levee is associated with an erosion scar along the river bank. Two sample locations are proposed to characterize the natural levee. The sample locations are:

RL-235+50-NE45 RL-239+00-NE15

- Historic Natural Levee: The historic natural levee is significantly larger than the natural levee. In the upstream central portion of the northeast bank of the reach, this historic natural levee is the feature adjacent to the river. This feature is located on the outside meander bend of a broad meander in the river. This feature is associated with an erosion scar. This feature is 900 feet long. One sample location is proposed to characterize this feature; RL-246+00-NE20.

- Floodplain: The floodplain present is located in the southern half of the reach on the northeast side of the river. The floodplain extends from 248+50 to the end of the reach. Two floodplain sample locations are proposed. The sample locations are:

RL-252+00-NE5 RL-258+50-NE5

- Low Terrace: The low terrace is adjacent to the river at the beginning of the reach on the southwest side of the river. The terrace is 150 feet long. The low terrace is associated with an erosion scar. One sample location is proposed to characterize this terrace; RL-235+50-SW10.

- Intermediate Terrace: The Intermediate Terrace is present at the start of the reach on the northeast side of the river. This terrace is 150 feet long. The intermediate terrace extends the entire length of the reach on the southwest side of the river. The intermediate terrace is associated with an erosion scar on the southwest side of the river except for a small portion of the bank in the center of the reach and for 450 feet at the end of the reach. Six sample locations are proposed to characterize the terrace. The sample locations are:

RL-235+50-NE35 RL-235+50-SW70 RL-239+00-SW10 RL-246+00-SW20
RL-252+00-SW5 RL-258+50-SW15

Away From Channel

- Natural Levee: The natural levee is separated from the river channel by a floodplain at Station 252+00. One sample location is proposed at RL-252+00-NE20.

- Historic Natural Levee: The historic natural levee is located on northeast side of the river. This feature is 200 feet long located in the upstream portion of the reach. The feature is proposed to be characterized with one sample location; RL-239+00-NE50.

- Wetland: The wetland areas are low elevation areas away from the river. The wetlands are located on both sides of the river. The wetland northeast of the river is 2,200 feet in length. Southwest of the river are two separate wetlands located in the central and downstream portions of the reach. The wetland in the central portion of the reach is 550 feet long. The downstream wetland is 950 feet long. The feature is proposed to be characterized by seven sample locations. The sample locations are:

RL-235+50-NE195	RL-239+00-NE145	RL-246+00-NE230	RL-246+00-SW265
RL-252+00-NE155	RL-252+00-SW320	RL-258+50-SW285	

- Low Terrace: The low terrace is located on both sides of the river. The northeast side low terrace is 2,350 feet long. This terrace is linear and at its widest point is 125 feet wide. The southwest side low terrace is geographically extensive (2,700 feet long and approximately 300 feet wide) and is the dominant geomorphic feature on the southwest side of the river. Fourteen sample locations are proposed to characterize the low terrace. The sample locations are:

RL-235+50-NE95	RL-235+50-SW460	RL-239+00-NE70	RL-239+00-SW150
RL-239+00-SW455	RL-246+00-NE95	RL-246+00-SW130	RL-246+00-SW330
RL-246+00-SW475	RL-252+00-NE80	RL-252+00-SW70	RL-252+00-SW410
RL-252+00-SW730	RL-258+50-SW125		

- Intermediate Terrace: The intermediate terrace is located on both sides of the river. The northeast side has three separate terraces; one in the upstream portion of the reach and two terraces at the end of the reach. The southwest side of the river has two terraces; one in the upstream half of the reach and the second in the center of the reach. Seven sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RL-235+50-SW130	RL-235+50-SW360	RL-239+00-NE30	RL-239+00-SW110
RL-239+00-SW335	RL-258+50-NE25	RL-258+50-NE550	

- High Terrace: The high terrace is located on both sides of the river. The northeast side of the river has three occurrences of the terrace; one in the central portion of the reach and two in the downstream portion. The high terrace in the central portion of the river is 1400 feet long. The terrace is geographically extensive in the downstream portion of the reach.

  The high terrace on the southwest side of the river extends the entire length of the reach. This terrace is linear in nature and is approximately 200 feet wide at its widest point. A second high terrace is located in the first 400 feet of the reach. Eleven sample locations are proposed to characterize the high terrace. The sample locations are:

RL-235+50-SW165	RL-235+50-SW525	RL-239+00-SW70	RL-246+00-NE55
RL-246+00-SW85	RL-252+00-NE60	RL-252+00-SW30	RL-258+50-NE60
RL-258+50-NE310	RL-258+50-NE765	RL-258+50-SW45	

- Upper High Terrace: The upper high terrace is higher in elevation than the high terrace, geographically extensive, and located on both sides of the river. The northeast side of the river consists of two occurrences which together extend the entire length of the reach. The width of this terrace varies from 175 feet to 675 feet.

  The upper high terrace on the southwest side of the river extends the entire length of the reach. This terrace is linear in nature and is approximately 900 feet wide at its widest point. Fourteen sample locations are proposed to characterize the upper high terrace. The sample locations are:

RL-235+50-NE430	RL-235+50-SW615	RL-239+00-NE595	RL-239+00-SW560
RL-239+00-SW905	RL-246+00-NE350	RL-246+00-NE750	RL-246+00-SW540
RL-246+00-SW725	RL-252+00-NE275	RL-252+00-NE580	RL-252+00-SW495
RL-258+50-NE945	RL-258+50-SW435		

Tributary

- Tributary: Two tributaries enter the river at the same station, one from the northeast and one from the southwest at Station 260+50. Two samples are proposed to be collected from the soil/sediment in the northeast tributary; RL-260+50-T-NE115 and RL-260+50-T-NE550. Two samples are proposed from the southwest tributary; RL-260+50-T-SW70 and RL-260+50-T-SW320.

5.3.13 Reach M (Station 261+50 to 286+00)

Reach M extends from an abandoned bridge on Smith Crossing Road at Station 261+50 to Station 286+00. Reach M includes a gradual meander with the overall reach flow direction towards the southeast (Attachment E, Figure 15).

The channel width of Reach M ranges from about 250 ft to 300 ft. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.001 ft/ft which suggests a relatively gradual channel slope. The geomorphic features are often geometrically linear, vary throughout the reach, and often correlate with distance from the river channel. There are no bank erosion control structures along the reach. Erosion scars occur on both banks throughout the reach.

The land use adjacent to the river in Reach M is predominantly woodland although there is some residential development in upland areas on the southwest bank. High terrace with smaller areas of intermediate terrace are the predominant geomorphic features throughout the reach that are adjacent to banks. Further from the river banks the typical geomorphic feature is low terrace with smaller areas of wetland. Beyond these low terrace/wetlands, the typical feature is a geographically extensive high terrace. Beyond the high terrace is a steep scarp and the upland area.

Proposed Sample Locations

A total of 62 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Two sample locations are proposed to characterize the soil/sediment from the tributary entering the river. Eleven different geomorphic features are represented in Reach M. The sample locations are included in 4 transects located perpendicular to the river. The transects are located at Stations 262+00, 268+00, 276+00, 284+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

<u>In-Channel</u>

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RM-276+00-IC-NE. The four transects for the in-channel sample locations are RM-262+00-IC, RM-268+00-IC, RM-276+00-IC, and RM-284+00-IC.

<u>Adjacent To Channel</u>

- <u>Natural Levee</u>: The natural levee is adjacent to the northeast side of the river from Station 270+00 to the end of the reach. The natural levee is associated with an erosion scar along the river bank. There is a small portion of the natural levee at the end of the reach on the southwest side of the river. Three sample locations are proposed to characterize the natural levee. The sample locations are:

  RM-276+00-NE20 RM-284+00-NE20 RM-284+00-SW30

- Floodplain: The floodplain present is located in the upstream portion of the reach and on the northeast side of the river. The floodplain extends from the start of the reach to 270+00. Two floodplain sample locations are proposed. The sample locations are:

  RM-262+00-NE5 RM-268+00-NE5

- Low Terrace: The low terrace is adjacent to the river at two locations on the southwest side of the river. The first is 450 feet long in the central portion of the reach. The second is 150 feet long near the end of the reach. The low terrace is associated with an erosion scar. Two sample locations will be used to characterize this terrace. The sample locations are:

  RM-276+00-SW60 RM-284+00-SW55

- Intermediate Terrace: The Intermediate Terrace is present at two locations on the southwest side of the river. The first is at the beginning of the reach and is 50 feet long. The second is 650 feet long in the downstream portion of the reach. The intermediate terrace is associated with an erosion scar. Two sample locations are proposed to characterize the terrace. The sample locations are:

  RM-262+00-SW20 RM-276+00-SW30

- High Terrace: The high terrace is located on the southwest side of the river in the upper third of the reach. The terrace is 950 feet long. The terrace is associated with an erosion scar. One sample location is proposed to characterize the terrace, RM-268+00-SW20.

Away From Channel

- Historic Natural Levee: The historic natural levee is located on both sides of the river. The upstream occurrence is on the southwest side of the river. This feature is 250 feet long. The downstream feature is present at the end of the reach and extends into Reach N. In Reach M, this feature is 350 feet long. The feature is proposed to be characterized by two sample locations. The sample locations are:

  RM-268+00-SW70 RM-284+00-NE90

- Wetland: The wetland areas are low elevation areas away from the river. The wetlands are located on both sides of the river. The wetland northeast of the river is 1,900 feet in length and is truncated by a tributary channel. Southwest of the river are two separate wetlands located in the downstream portion of the reach. Together these wetlands are 550 feet in length. The feature is proposed to be characterized by four locations. The sample locations are:

RM-268+00-NE250	RM-276+00-NE360	RM-284+00-NE360	RM-284+00-SW125

- Low Terrace: The low terrace is located on both sides of the river. The northeast side low terrace encircles the wetland and is present adjacent to the floodplain for the first 500 feet of the river. This terrace is 2,100 feet long. The southwest side low terrace is two separate terraces. The upstream portion is 1,100 feet long. The downstream portion is 1,000 feet long. Eleven sample locations are proposed to characterize the low terrace. The sample locations are:

RM-262+00-NE15	RM-262+00-SW145	RM-268+00-NE190	RM-268+00-NE320
RM-268+00-SW130	RM-276+00-NE190	RM-276+00-NE500	RM-276+00-SW220
RM-284+00-NE215	RM-284+00-NE450	RM-284+00-SW170	

- Intermediate Terrace: The intermediate terrace is located on both sides of the river. The northeast side has two separate terraces; one in the central portion of the reach and one at the end of the reach. The southwest side of the river has one terrace that is 1,450 feet long. This terrace starts near the start of the reach and ends near the wetlands at the downstream end of the reach. Six sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RM-268+00-NE35	RM-268+00-SW335	RM-276+00-NE130	RM-276+00-SW90
RM-276+00-SW310	RM-284+00-NE40		

- High Terrace: The high terrace is located along the entire length of the reach on the northeast side of the river. This terrace is geographically extensive and dominant in this reach. It is approximately 1,300 feet wide from the river to the upland scarp.

  The terrace is located in two locations on the southwest side of the river. The upstream location is 600 feet long in the upstream half of the reach. This terrace is located adjacent to the upland scarp. The downstream terrace is located at the end of the reach, is 500 feet long, and is adjacent to the upland scarp. Sixteen sample locations are proposed to characterize the high terrace. The sample locations are:

RM-262+00-NE40	RM-262+00-NE255	RM-262+00-SW60	RM-268+00-NE20
RM-268+00-NE570	RM-268+00-SW410	RM-276+00-NE50	RM-276+00-NE550
RM-276+00-NE1120	RM-276+00-NE1740	RM-284+00-NE55	RM-284+00-NE140

RM-284+00-NE510 RM-284+00-NE1045 RM-284+00-SW60 RM-284+00-SW205

- Upland: The upland area present in this reach is at the borders of the geomorphic features and is typically a steep scarp to a flat upland area. The upland on the southwest side of the river has a flatter gradient than is typically the case. This is at the end of the southwest portion of transect 268+00. This upland area is proposed to characterized by one sample location at RM-268+00-SW465.

Tributary

- Tributary: A tributary enters the river from the northeast at Station 280+00. Two samples are proposed to characterize the soil/sediment in this tributary; RM-280+00-T-NE80 and RM-280+00-T-NE335.

5.3.14 Reach N (Station 286+00 to 320+00)

Reach N extends from Station 286+00 to a location that is physically distinguished by channels that dissect both river banks near Station 320+00. Reach N includes a gradual meander with the overall reach flow direction towards the southeast (Attachment E, Figure 16 and 17).

The channel width of Reach N ranges from about 250 ft to 300 ft. The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.001 ft/ft which suggests a relatively gradual channel slope. The geomorphic features are often geometrically linear, vary throughout the reach, and often correlate with distance from the river channel. There are no bank erosion control structures along the reach. Erosion scars occur on both banks throughout the reach. The land use adjacent to the river in Reach N is predominantly woodland although there is some residential development in upland areas on the southwest bank.

The primary features throughout the reach that are adjacent to river banks include high terrace, intermediate terrace, and floodplain. Further from the northeast bank in the upper and lower reach, there are areas of low terrace and intermediate/high terrace, respectively, prior to upland. In the mid-reach, upland encroaches on the river, limiting the area of other geomorphic features. Further from the southwest bank, substantial low terrace and wetland areas occur as compared to the northeast bank.

Proposed Sample Locations

A total of 65 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Two sample locations are proposed to characterize the tributary to the river. Ten different geomorphic features are represented in Reach N. The sample locations are included in 4 transects located perpendicular to the river. The transects are located at Stations 290+50, 297+00, 305+00, 316+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

In-Channel

Twelve in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RN-290+50-IC-NE. The four transects for the in-channel sample locations are RN-290+50-IC, RN-297+00-IC, RN-305+00-IC, and RN-316+00-IC.

Adjacent To Channel

- Natural Levee: The natural levee is adjacent to the river at approximately 80% of the reach. The natural levee is located on both river banks. Five sample locations are proposed to characterize the natural levee. The sample locations are:

  RN-290+50-SW40 RN-297+00-NE25 RN-297+00-SW20
  RN-316+00-NE30 RN-316+00-SW30

- Floodplain: The floodplain present is intermittent in extent and located on the northeast side of the river. The longest extent is on the outside of the gradual meander bend. One floodplain sample is proposed. The sample location (RN-305+00-NE10) is representative of the floodplain in the gradual meander in the reach.

- Intermediate Terrace: The Intermediate Terrace is adjacent to the river channel at three locations in Reach N. Three sample locations are proposed to characterize the terrace. The sample locations are:

  RN-290+50-NE15 RN-290+50-SW30 RN-305+00-SW30

Away From Channel

- Natural Levee: The natural levee is separated from the river channel by a floodplain. One sample is proposed at RN-305+00-NE25. At 305+00 the natural levee turns away from the river channel. This natural levee is proposed to be characterized with one sample at RN-305+00-SW100.

- Historic Natural Levee: The historic natural levee is only found on the northeast side of the river. This feature is present along approximately 60% of the northeast side of the river. The feature is proposed to be characterized by three locations. The sample locations are:

RN-290+50-NE100	RN-297+00-NE110	RN-316+00-NE110

- Wetland: The wetland areas are low elevation areas away from the river. The wetland is only located southwest of the river. The wetland extent is approximately 85% of the length of the reach. The feature is proposed to be characterized by four locations. The sample locations are:

RN-297+00-SW370	RN-305+00-SW520	RN-316+00-SW290	RN-316+00-SW570

- Low Terrace: The low terrace is a large feature located on both sides of the river. The terrace is present at varying distances from the river. Seventeen sample locations are proposed to characterize the low terrace. The sample locations are:

RN-290+50-NE40	RN-290+50-NE210	RN-290+50-NE1320	RN-290+50-SW280
RN-297+00-NE70	RN-297+00-NE165	RN-297+00-NE1270	RN-297+00-NE1370
RN-297+00-SW100	RN-297+00-SW200	RN-297+00-SW590	RN-305+00-SW135
RN-305+00-SW275	RN-305+00-SW905	RN-316+00-NE1315	RN-316+00-SW175
RN-316+00-SW450			

- Intermediate Terrace: The intermediate terrace is located at the downstream end of Reach N and is separated from the river by the natural levee on both sides of the river and is more spatially extensive on the northeast side of the river. Five sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RN-305+00-NE45	RN-316+00-NE30N	RN-316+00-NE215	RN-316+00-NE395
RN-316+00-SW100			

- High Terrace: The high terrace is located along the entire length of the reach on the northeast side of the river. The terrace is located from the beginning of the reach to the halfway point of the reach on the southwest side of the river. Thirteen sample locations are proposed to characterize the high terrace. The sample locations are:

RN-290+50-NE130	RN-290+50-NE465	RN-290+50-NE1160	RN-290+50-SW75

RN-297+00-NE890	RN-297+00-NE1020	RN-297+00-SW40	RN-305+00-NE80
RN-305+00-SW210	RN-316+00-NE30S	RN-316+00-NE295	RN-316+00-NE495
RN-316+00-NE885			

- Upland: A large oval shaped upland is present northeast of the river extending from the start of the reach to 500 feet from the end of the reach. This upland area is proposed to be characterized by three sample locations on the river side of the feature. The sample locations are:

RN-290+50-NE510	RN-297+00-NE240	RN-305+00-NE145

Tributary

- Tributary: A tributary enters the river from the northeast at Station 319+00. Two samples are proposed to characterize the soil/sediment in this tributary; RN-319+00-T-NE135 and RN-319+00-T-NE850.

5.3.15 Reach O (Station 320+00 to 335+50)

Reach O extends from a location that is physically distinguished by a cabin on the southwest bank and channels that dissect river banks at Station 320+00 to downstream from Rodgers Road at Station 335+50. Reach O includes a gradual meander that shifts the flow direction slightly towards the east. The overall reach flow direction is towards the southeast (Attachment E, Figure 18).

The channel width of Reach O ranges from about 250 ft to 350 ft. The maximum channel width is in the upper segment .The hydraulic gradient of the channel reach, based on available LiDAR data, was less than 0.001 ft/ft which indicates a relatively gradual channel slope. The geomorphic features are often geometrically linear and vary in type and area throughout the reach. There are no bank erosion control structures along the reach. Erosion scars occur on both banks throughout the reach. The land use adjacent to the river in Reach O is predominantly woodland although there is some residential development in upland areas on the southwest bank.

High terrace is the primary feature on both banks adjacent to the channel. A narrow band of floodplain is located on the northeast bank adjacent to the channel near the Reach O/P boundary. Further from the northeast bank along most of the reach there is a band of intermediate terrace followed by relatively extensive areas of low terrace, wetland, and intermediate terrace. Low or intermediate terrace are the predominant features further from the channel on the southwest bank. An extensive upland is beyond the terrace features on the southwest bank.

Proposed Sample Locations

A total of 65 in-channel and overbank sample locations are proposed to characterize in-channel, floodplain, natural levees, low terrace, intermediate terrace, high terrace, and upland locations. Two sample locations are proposed to characterize the tributary to the river. Nine different geomorphic features are represented in Reach O. The sample locations are included in five transects located perpendicular to the river. The transects are located at Stations 320+00, 322+50, 325+50, 327+50, and 333+00. Sample locations are defined in terms of proximity to channel (away or adjacent) and geomorphic features.

In-Channel

Nine in-channel sample locations are proposed. In-channel samples, designated as IC in the sample location identification, are located along each channel bank designated as NE for northeast portion of the river, SW for southwest portion of the river, and C for the center of the channel at each transect. An example of a sample location identification is RO-327+50-IC-NE. The three transects for the in-channel sample locations are RO-322+50-IC, RO-327+50-IC, and RO-333+00-IC.

Adjacent To Channel

- Natural Levee: The natural levee is adjacent to the river at approximately 85% of the reach on the northeast side of the river and 100% of the river on the southwest side of the river. Four sample locations are proposed to characterize the natural levee. The sample locations are:

  RO-320+00-NE10 RO-320+00-SW10 RO-325+50-NE10 RO-333+00-SW10

- Floodplain: The floodplain is limited in extent on the northeast side of the river. The floodplain is 250 feet long. One floodplain sample is proposed;

  RO-333+00-NE5

Away From Channel

- Natural Levee: The natural levee away from the channel is located on the northeast side of the river. The levee is located inland of the floodplain in this portion of the reach. This levee is 250 feet long. The feature is proposed to be characterized by one sample location;

  RO-333+00-NE10

- Historic Natural Levee: The historic natural levee is only found on the northeast side of the river. This levee is present in four distinct areas. The longest historic natural levee is 300 feet long. The levee is proposed to be characterized by two sample locations. The sample locations are:

RO-320+00-NE40	RO-333+00-NE80

- Wetland: The wetland areas are low elevation areas away from the river. The wetlands are present on both sides of the river. The northeast wetland is 1300 feet long. The southwest wetland is the end of a larger wetland complex in Reach N. This wetland is 100 feet long. The feature is proposed to be characterized by three locations. The sample locations are:

RO-320+00-SW210	RO-325+50-NE450	RO-333+00-NE300

- Low Terrace: The low terrace is a large feature located on both sides of the river. The terrace is present at varying distances from the river. Nineteen sample locations are proposed to characterize the low terrace. The sample locations are:

RO-320+00-NE160	RO-320+00-NE420	RO-320+00-NE1375	RO-320+00-SW25
RO-320+00-SW120	RO-320+00-SW275	RO-320+00-SW450	RO-325+50-NE90
RO-325+50-NE385	RO-325+50-NE515	RO-325+50-NE1730	RO-325+50-SW40
RO-325+50-SW145	RO-333+00-NE160	RO-333+00-NE350	RO-333+00-NE505
RO-333+00-NE1165	RO-333+00-NE1880	RO-333+00-SW315	

- Intermediate Terrace: The intermediate terrace is located along the length of the reach on the northeast side of the river. It occurs in three areas on the southwest side. The longest terrace on the southwest side of the river is 800 feet long. Eight sample locations are proposed to characterize the intermediate terrace. The sample locations are:

RO-320+00-NE85	RO-320+00-SW45	RO-325+50-NE70	RO-325+50-SW190
RO-333+00-NE115	RO-333+00-NE440	RO-333+00-SW60	RO-333+00-SW240

- High Terrace: The high terrace is located along the entire length of the reach on both sides of the river. The terrace is geographically extensive on the northeast side of the river. Fifteen sample locations are proposed to characterize the high terrace. The sample locations are:

RO-320+00-NE25	RO-320+00-NE60	RO-320+00-NE635	RO-320+00-NE765
RO-320+00-NE1130	RO-320+00-SW80	RO-325+50-NE45	RO-325+50-NE840
RO-325+50-NE1340	RO-325+50-SW20	RO-325+50-SW245	RO-333+00-NE35

RO-333+00-NE680 RO-333+00-NE1000 RO-333+00-SW30

- Upland: A large oval shaped upland is present northeast of the river extending from the start of the reach to the end of the reach. This upland is proposed to be characterized by three sample locations on the river side of the feature. The sample locations are:

RO-320+00-NE500 RO-325+50-NE560 RO-333+00-NE590

Tributary

- Tributary: A tributary enters the river from the southwest at Station 322+00. Two samples will are proposed to characterize the soil/sediment in this tributary; RO-322+00-T-SW80 and RO-322+00-T-SW205.

5.4 PROCEDURES

5.4.1 Sediment and Soil Sampling

In-channel sediment and over-bank soil sampling will be conducted to characterize soil profiles and establish TA concentrations. The methods to be used for in-channel and overbank sampling are summarized in Section 5.4.1.1 and 5.4.1.2. In most cases, the sampling will be conducted in transects perpendicular to the river. A transect may include in-channel samples and overbank samples to determine the depositional environment in that sub-reach of the river. For similar segments of the river, the data collected from these transect locations can be extrapolated upstream and downstream due to the geomorphic setting. The following procedures will be used for in-channel sediment and overbank soil sampling in the UTR Project.

5.4.1.1 In-Channel Sediment Poling/Sampling

In-channel sediment poling is conducted to assess the location and extent of significant sediment deposits to determine the representative sample locations. In-channel sediment deposit thickness was previously characterized by LTI in November and December, 2003 and again in April 2006 by ATS. Although this information is adequate for conceptual planning, an updated sediment inventory and preliminary sampling is required to determine the preferential deposition pattern of in-channel sediment, the sediment composition, and the contaminant concentrations. The preliminary sampling will provide data needed to design a sampling strategy that will be used in the future in advance of corrective action activities.

5.4.1.1.1 *Sediment Inventory*

The sediment inventory can be conducted in UTR reaches using chest waders and walking in the river channel during low flow conditions. However, upstream of the Dow Dam and higher flow conditions will require the use of a sampling vessel. The sediment inventory will be conducted with a metal pole to measure the water depth from the water surface to the top of the sediment (recorded to the nearest tenth of a foot). The metal pole will then be pushed into the sediment until refusal. The total depth, minus the depth to sediment, yields an estimate of the sediment depth. This technique is adequate in this setting due to the underlying clay from the glacial lake bed or glacial till which will provide a refusal boundary.

The sediment inventory data will be used to produce a map that describes in relative terms the type of the river channel bottom. The channel bottom terms used include: soft sediment (silts and clays), sandy bottom, gravel bottom, or cobble and boulder bottom. The channel bottom types and relative shapes will be depicted on field maps for each reach by drawing polygons, which graphically represent "sediment deposits."

5.4.1.1.2 *Sediment Sampling*

The in-channel sediment sampling will be conducted from the top of the sediment into the underlying native material (channel bed, lacustrine clay, clay till) unless refusal due to bedrock or some other physical obstacle is encountered. The water depth will be measured prior to sediment sampling at each location. Sampling will be conducted using chest waders (shallow water) or a sampling vessel (deeper water).

The sediment core sampler length will be determined upon completion of the sediment inventory. The sediment thickness will determine the length of the acetate liner. The acetate liner or sediment sampler will be advanced slowly into the sediment to minimize compaction. In some cases, sediment less than 1 foot thick with water depths less than 2 feet, an acetate liner may be pushed by hand.

Sediment profile descriptions are differentiated by color, texture, or unique features. Each sediment layer will be described by its sediment color (Munsell Color Chart), texture (USCS/Unified Soil Classification System; USDA-SCS/United Stated Department of Agriculture Soil Classification System), plasticity, cohesiveness, sand/gravel content, or unique features such as shell fragments, mottles, or organic matter. This information will be recorded on Sediment/Soil Core Data Forms.

The in-channel sample locations within a reach will be determined based on the variety of channel bottom types, dimensions, and relative distribution of each observed in the field. As indicated in Attachment A,

Table 1, at least two samples will be collected from each sediment sample location: one sample of the overlying sediments, and one sample of the native material.

If the sediment illustrates distinct layering, discrete interval samples may also be collected based on the best professional judgment of the field sampling team leader. The interval for the sediment samples used for chemical analysis will be based on the sediment profile description and specifically distinct sediment layers. If the sediment is layered, samples will be collected from each layer to determine the TA concentrations in each sediment layer. If the sediment is homogeneous, the sample interval will be the entire sediment profile. At a minimum, a second sample will be collected from the native material.

Figures 1 through 18 in Attachment E may show only one in-channel sample at a particular location, more than one sample location may be sampled based on the sediment inventory mapping and the channel bottom types. Gravel, cobble, and boulder bottom samples will not be collected as these benthic environments are difficult to sample and do not typically contain significant TA concentrations. A default concentration for these sample types will be established for these benthic environments.

5.4.1.2 Overbank Soil Sampling

Overbank soil sampling is conducted to determine the TA concentration extent horizontally and vertically for the geomorphic features within a reach. The horizontal extent is determined by the sample location, geomorphic feature, and the distance from the river. The vertical extent is determined by the soil horizon, contaminant concentration by depth, and presence of native material.

5.4.1.2.1 Sample Collection

The soil sampling techniques used to collect the soil cores vary based on thickness of the soil core. For shallow soil sampling, less than 5 feet, it is anticipated that a hand operated stainless steel sampling tube with an acetate liner will be used. The sampling tube is driven into the ground using a deadblow hammer. A sampling tube is either 12 or 18 inches in length. For soils that cave in or for core depths greater than 5 feet, a Geoprobe® with casing and an acetate liner may be used for soil sampling.

A 1-foot stainless steel sampling tube with acetate liner will be used to collect samples for soil profile descriptions and for chemical analysis. After the sampling tube soil core is collected from a particular interval (e.g., 0.0 to 1.0 foot), a bucket auger will be used to auger down over the recently collected interval so the soil tube with a new acetate liner can be used to sample the next sampling interval, without interference from the sidewall of the previous interval.

5.4.1.2.2 *Soil Profile Descriptions*

Soil horizons are determined based on pedogenic processes or vertical or lateral accretion sediment deposition characteristics. A soil profile description will be completed for each horizon. The soil profile description includes soil color (Munsell Color Chart), USCS soil texture, USDA-SCS soil texture, moisture, organic content, mottling, clay skin development, and other soil features such as the presence of shell fragments, sand or gravel lenses, iron concretions or odors. The soil profile description will be recorded on Sediment/Soil Core Data Forms. Soil profile descriptions will be completed to the depth of the native soil horizon.

5.4.1.2.3 *PCOI/TAL Sampling*

Following completion of the soil profiles, sample intervals or subsamples will be selected for chemical analysis based on geomorphic setting and soil horizons. Although soil cores will be obtained in 1-foot intervals, the sample interval specified for chemical analysis will be selected based on the soil horizons. Samples will be collected by soil horizon to determine the extent of impact. The target soil core sampling depth based on the soil survey and methods are provided in Attachment A, Table 1.

5.4.1.2.4 *Erosion Scar Sampling*

The erosion of contaminated soil into the Tittabawassee River from the river banks may re-mobilize TAs into the river. Erosion scars along the river banks are observable in areas where erosion may be occurring and are caused by the flow of floodwaters along the river bank face during flood stage or more consistently from undercutting of river banks due to daily fluctuation in the river flow resulting from discharges from the Sanford Dam. The erosion scar face represents the soil present in the feature deposit that has not eroded but has been disturbed through the erosion process. Data collected from the erosion scar provides information on soil that has the potential to erode into the river, but is difficult to relate to the depositional or geomorphologic features. This information is valuable for identification of potential re-mobilization to the river, but this information should not be used to interpret geomorphic features.

Erosion scar sampling will be conducted following characterization of the adjacent geomorphic feature that is being eroded. The vertical profile of the adjacent geomorphic feature will include soil horizon determination, soil profile descriptions by soil horizon, and analytical data based on the soil horizons. The results of the soil profile description and analytical data will provide information on the contaminant concentrations within the soil horizon. Based on these data, select erosion scar locations may be sampled. Erosion scar samples will be collected using an acetate liner pushed horizontally into the river bank to a depth of 6 inches.

5.4.2 Statistical Calibration and Verification of *GeoMorph*™

A principle of the *GeoMorph*™ sampling design is that there is correlation between the variation in furans and dioxin concentrations in the floodway soils that are associated with distinct fluvial deposition areas. This is based on the relationship between fluvial systems and sediment deposition that are best characterized through geomorphologic principles and fluvial processes. The *GeoMorph*™ sampling design is based on collecting representative soil sampling from distinct fluvial geomorphic features to characterize the furan and dioxin concentrations associated with the soils from these geomorphic features.

MDEQ has expressed a desire to statistically calibrate and verify the *GeoMorph*™ sample design by comparing the efficiencies and results generated by the *GeoMorph*™ process to that of random sampling designs. In general, standard statistical protocols will be applied to select the most appropriate statistical test(s) based on evaluations of the data set(s). The evaluations will consider a number of variables including the number of data values, satisfaction of normal distribution model assumptions (independence, normal distribution), and potential influence of outliers on data analyses to select the most appropriate parametric and/or nonparametric statistical tests. Overall, four separate approaches will be used to support the *GeoMorph*™ sampling design.

- The first procedure evaluates the assumption that part of the variation in the concentrations of furans and dioxins in floodway soils can be explained by accounting for fluvial deposition areas in the floodway.

- The second procedure will be utilized to evaluate outliers in furan and dioxin concentrations within geomorphic features during the field activities so that these outliers can be addressed in a consistent and timely manner.

- The third and fourth procedures compare the biased *GeoMorph*™ sampling design to random sampling designs.

The statistical calibration and verification of *GeoMorph*™ will be an ongoing process throughout the implementation of the SAP. The following sections provide an overview of the statistical tools that will be utilized as part of the *GeoMorph*™ SAP to assess the adequacy of site characterization. The Technical Memorandum that describes the statistical and calibration approach is included in Attachment H.

5.4.2.1 Screening for Outliers in Geomorphic Features

Abnormally high and low concentrations of furans and dioxins in a geomorphic feature will be identified and addressed during the field activities. Identifying and addressing these outliers early and during the active field period will improve the quality and coverage of the final data set generated on the UTR project.

Initially, the furan and dioxin concentrations from each geomorphic surface within a given reach will be screened for outliers. A graphical evaluation of each population (i.e., each geomorphic feature and similarly mapped geomorphic features within a given reach) will be performed to look for potential outliers and to evaluate the assumptions about the distribution of the data required for analysis of variance (ANOVA) and required for the outlier test described below. The data and log transformed data will be separately represented in box plots and probability plots. The distribution of data in each population will be evaluated from these plots. Each data set will be evaluated for both normal and lognormal distributions. The results of these evaluations will be compared to determine which distribution provides a better fit to the data.

After initial screening, a formal test will be performed if the presence of one or more outliers is suspected following the procedures in the statistical training material provided by the MDEQ (S3TM: MDEQ, 2002b; Section 2.1.4). If only one outlier is suspected based upon the graphical representation, then Grubbs' test will be utilized. If multiple outliers are possible based upon the graphical representations, then Dixon's Test will be used if the sample size is equal to or less than 25, and Rosner's test will be utilized for sample sizes larger than 25.

These tests will be utilized when there are at least four detectable concentrations in the population. If there are less than four detectable concentrations in the population, only graphical methods will be used to evaluate possible outliers. Censored data (not detectable concentrations) will be addressed using the procedures presented in the section on ANOVA. Prior to performing Dixon's Test, the data distribution will be evaluated graphically. If the data are assumed to be normally distributed, then the un-transformed data will be utilized. If the data are assumed to be log normally distributed, then the data will be log transformed prior to use in tests.

All data that are identified as outliers will be evaluated. S3TM (MDEQ, 2002b; p 7.42) provides the following partial list of possible causes for outliers:

- errors in sampling, laboratory analysis, data entry, or transcription;

- an accurate result sampled from a different population;
- an accurate but extreme value from the original population;
- an accurate value that appears to be extreme because of failure to obtain a representative sample, due to insufficient number of samples or biased sampling.

In consideration of the need to evaluate each outlier or set of outliers identified, one of the following actions will be taken.

1. Laboratory records will be reviewed for possible errors in analysis, data entry, or transcription.
2. The geomorphic feature will be evaluated to determine if field data support the conclusion that there may be more than one feature present. If there is supporting evidence to re-classify part of the geomorphic feature, then the geomorphic feature may be re-defined or split into multiple features to address the data generated from the study.
3. The outlier may appear to accurately represent the variation within a geomorphic feature, and the outlier may be accepted as part of the geomorphic feature.
4. Additional soil samples may be collected and analyzed to further evaluate and delineate the outlier within a mapped geomorphic feature.

Performing the outlier evaluation at a 95 percent level of confidence (i.e., $\alpha = 0.05$), it is expected that one out of every 20 comparisons will identify an outlier even if there are no outliers present in any data set. Furthermore, when testing for multiple outliers (potentially three outliers evaluated in every data set), the potential frequency of falsely identifying outliers increases. There are 15 reaches being evaluated, and there are typically more than six features in each reach. Therefore, it is expected that over 100 comparisons will be made. With this number of comparisons, it is expected that multiple tests will falsely identify an outlier when one does not exist. In addition, the outlier test assumes normality. With the small data sets that will be tested, we will not be able to provide a statistically robust test of this assumption. Some populations will likely not be normal or lognormal. The expectation that distributional assumptions will be incorrect in some cases increases the probability of falsely identifying an outlier when no outlier actually is present. Therefore, not all outliers will be eliminated from the data set, but each outlier will be reviewed with the MDEQ, and addressed in the final report. The outlier evaluation is included to screen the rapid turnaround analytical data and to focus additional sampling and field mapping activities within the 2006 *GeoMorph*™ sampling program.

5.4.2.2 Evaluate GeoMorph™ Stratification

Through the course of the proposed work, soil borings will be set at hundreds of sample locations and thousands of soil samples will be analyzed for furans and dioxins. Each of these sample locations will be specifically tied to a geomorphic feature as well as other aspects that describe the sample location such as a distance from the river bank, a distance from Midland, and an elevation. Initially, an ANOVA will be performed to determine whether geomorphic features explain a significant amount of the variation in the furan and dioxin concentrations. The S3TM (MDEQ, 2002b; p. 4.25) supports the use of ANOVA to evaluate if "analytical results differ significantly among strata", and whether use of the strata are "necessary and statistically valid."

ANOVA will be conducted on a subset of furan and dioxin congener concentration data of greatest quantitative significance for characterizing extent and distribution of impacts and for risk assessment. The distribution of concentrations within each *GeoMorph*™ stratum will be evaluated for consistency with normal or lognormal distributions, to determine whether it is more statistically appropriate to perform ANOVA on concentrations or the logarithm of concentrations. The prevalence of non-detects (censored data) and outliers will also be addressed, as described below in this section. If the data set(s) do not support the assumption of a normal or lognormal distribution, then a nonparametric statistical comparison may be utilized to evaluate the variation in the furan and dioxin concentrations. The detailed statistical procedures are described in a Technical Memorandum and are included in Attachment H.

5.4.2.3 Comparison to Random-On-Grid Sampling Design Method

The objective of this evaluation is to compare the data generated from a *GeoMorph*™ biased transect sample design, to the data generated from a random-on-grid sample design, an alternative sampling strategy discussed in S3TM (MDEQ, 2002b; p 4.24). For this purpose, an existing random-on-grid dataset will be employed. It is proposed that data from Scoping Study Area 1 (CH2M Hill, 2005c) be used for this comparison. The comparison will examine differences in uncertainty bounds of mean predicted concentrations using the two strategies. This will include a comparison of 95 percent upper confidence limits of means, as well as lower confidence limits of mean predictions, and will be supported by a comparison of other summary statistics generated by the alternative strategies. The detailed statistical procedures are described in a Technical Memorandum and are included in Attachment H.

5.4.2.4 Comparison to Fixed Interval Transect Sampling Design Method

The objective of this evaluation is to compare the data generated from a *GeoMorph*™ biased transect sample design, to the data generated from a fixed interval transect sample design (i.e., MDEQ Validation Transect Design). This evaluation will compare the data generated on selected validation transects, where a tighter boring interval is maintained, to the data generated with the *GeoMorph*™ biased transect sampling design through the same reach. The data will be used to evaluate the measured concentrations of furans and dioxins within the floodway soils using the fixed interval transect approach versus a *GeoMorph*™ biased transect sampling approach. The detailed statistical procedures are described in a Technical Memorandum and are included in Attachment H.

5.4.3 Decontamination and Sample Handling

At a minimum, all non-disposable and non-dedicated sampling equipment will be decontaminated prior to initial use, between sample intervals, and between sampling locations. Equipment decontaminated prior to field use will be stored in a sealed plastic bag to prevent contamination. All equipment used in sampling, including stainless steel bowls and utensils, will be decontaminated by washing with a laboratory grade soap solution, and triple rinsing with water (tap water followed by two deionized or distilled water rinses) and air-dried. Decontamination water will be collected and containerized for proper disposal.

Samples will be packed on ice, delivered to and/or shipped via overnight courier to the laboratory. The applicable laboratories will analyze the samples for target furans and dioxins using USEPA 1613-TRP/RT. The furans and dioxins analysis will have a fast turnaround from sample collection to availability of results. This rapid analytical turnaround will allow the sampling team to collect additional step-out sampling as warranted, to define in near real time the vertical and horizontal extent of contamination prior to demobilization from the project area. Decontamination and sample handling procedures are described in the UTR Project QAPP.

5.4.4 Sample Location and Field Positioning

All sample locations will be staked and/or surveyed during the project to the extent practicable using a Real-Time Kinematic Global Positioning System (RTK/GPS) and/or Differential Global Positioning System (DGPS), with a coordinate accuracy of +/-1 meter (x, y), and vertical control of +/-0.01 foot msl. The horizontal coordinate system shall be the Michigan State Plane Coordinate System, South Zone, NAD 83, in international feet. The vertical datum shall be NAVD 88. In some cases trees or other obstructions may interfere with RTK/GPS or DGPS signals and require survey by Electronic Total Station or measurement from landmarks clearly visible on the site topographic maps. If an unreasonable error is found, outside +/-1 meter accuracy, a registered surveyor will be used to reconcile the discrepancy. Sample location and field positioning procedures are detailed in the UTR Project QAPP.

5.4.5 Field Documentation and Recordkeeping

5.4.5.1 Field Sample Data Collection Forms

Field data forms will serve as a daily record of events, observations, and measurements during all field activities. All information relevant to sampling activities will be recorded on these forms. Entries on these forms will include:

- Names of field crew
- Date and time of site entry and exit
- Location of sampling activity
- Sampling method
- Number and volume of samples collected
- Date and time of sample collection
- Sample identification number
- Field measurements
- Field observations

Complete forms will be maintained for quality assurance purposes. As appropriate, field Quality Assurance corrective actions will be recorded in field data forms, memos, or in the Corrective Action Logbook maintained for the project. These records will become part of the permanent project file.

5.4.5.2 Chain of Custody and Shipping

Field personnel are responsible for the care and custody of samples until they are transferred or shipped. As few people as possible should handle the samples. Field personnel will complete sample labels and chain-of-custody forms in waterproof ink, at the time of collection. The label will include the project number, unique sample identification number, date and time of collection, and type of sample. All samples will be placed on ice in the field to keep them cool and throughout packaging and transport. When transferring possession or shipping samples from UTR project, the individuals relinquishing and receiving will sign, date, and note the time on the chain of custody form.

Samples will be properly packaged for shipment in strong, tamperproof containers that are uniquely identified. The containers will be secured with strapping tape and with signed and dated custody seals. Samples sent by commercial carrier will include a bill of lading with a unique record number for computer tracking of the shipment. This tracking number will be recorded as part of the permanent custody documentation. Commercial carriers are not required to sign off on the custody record provided the custody forms are sealed inside the shipping container and the custody seals remain intact.

Upon receipt of the samples at the laboratory a Sample Receipt Form (SRF) will be completed in addition to the chain of custody record. The SRF will document the condition of the chain of custody seal and the samples at the time of receipt. It will also list the laboratory storage location for the samples.

5.5 DATA QUALITY OBJECTIVES AND REQUIREMENTS

5.5.1 Project Data Quality Objectives - Upper Tittabawassee River *GeoMorph*™ Investigation of Contaminated Soils and Sediment

The purpose of the UTR *GeoMorph*™ SAP is to define a plan for an optimized, geomorphology-based, investigation that will result in a site characterization sufficient to support the evaluation and selection of risk management options in the river channel sediments and floodplain soils. The project Data Quality Objectives (DQOs) outlined in this section form the fundamental objectives for the investigative plan outlined in detail in Section 5. The type and quality of data needed to address the project DQOs are also identified to address potential problems before sampling and analysis begin. The selection of COI/TAL constituents and statistical approaches that will be used to evaluate data generated from the UTR *GeoMorph*™ investigation are described in Attachments F and H respectively.

5.5.1.1 Project Data Quality Objectives Process

The DQO process is a planning tool used to ensure that only that data needed to support the risk management decision-making process is collected, and to ensure that sufficient data of sufficient quality and precision are collected so that informed decisions can be made. An important element of the *GeoMorph*™ investigation approach is that sampling activities will be guided by near-real-time (NRT) feedback from the laboratory analysis work to ensure the sufficiency of the data in satisfying the DQOs. The laboratory validation and quality control processes built into the laboratory procedures (as described in UTR Project QAPP) will assure the quality and precision of the laboratory data will serve the needs of the DQOs. By having high quality data flowing back to sampling personnel on a NRT basis, sampling locations and depths can be adjusted or iterated in the field to assure that an adequate number of representative samples are collected and the nature and extent of TA constituents are understood before sampling crews leave the field. The iterative process structure for the *GeoMorph*™ site characterization is outlined in Attachment I and will be used throughout the implementation of the *GeoMorph*™ SAP.

5.5.1.2 GeoMorph™ SAP Data Quality Objectives

The USEPA guidance document, *Guidance for the Data Quality Objectives Process* (USEPA, 2000) was used in formulating the following DQOs for the UTR *GeoMorph*™ SAP activities. The principal objectives for data gathering during the UTR *GeoMorph*™ investigation are defined as follows:

1. Identify the COIs that may have been released to the Tittabawassee River from historical operations at The Dow Chemical Company (Dow) Midland Plant.
2. Identify Near Plant TAL and Downstream TAL, which will be subsets of the COI list, based on evaluation of environmental fate and transport, persistence, toxicity, and other relevant factors;
3. The rapid turnaround laboratory analysis of furans and dioxins will be conducted to address a threshold for environmental concern of approximately 100 ppt TEQ. Individual furan and dioxin congeners will be quantitated to a level at or below 10 ppt TEQ, yielding a reporting limit for the aggregated congener concentration of 50 ppt TEQ or less. Therefore, depending on the particular purpose, these data may be useful for environmental evaluations substantially below 100 ppt TEQ;
4. Characterize the distribution of TA in in-channel sediment and floodplain soils based on the geomorphic model, as follows;
    a. Provide information on the horizontal and vertical distribution of furans and dioxins and other TA in in-channel sediment;
    b. Characterize the horizontal and vertical distribution of furans and dioxins and other TA constituents in floodplain soils;
    c. Characterize the impacts of anthropogenic features on the deposition and scour of furans and dioxins and other TA constituents.
5. Characterize the distribution of furans, dioxins, and other TA constituents across soil and sediment characteristics of interest, such as soil type, grain size and density, carbon content and type, and location within "like-character" geomorphic features, and distance from the river channel.
6. Characterize the fate and transport mechanisms and develop predictive tools for the soil and sediment fractions of interest and associated TA constituents in the river and floodplain to support evaluation and selection of risk management options.

7. Identify areas of the river and floodplain acting as secondary sources for downstream transport of TA constituents that may be candidate areas for early or interim response activities, pilot study activities, institutional controls, and/or further investigations.
8. Identify areas of the floodplain where ongoing accretion of clean soils will isolate soils contaminated with TA constituents in a reasonable period of time, as well as those areas where accretion rates need to be supplemented with other risk management options such as institutional use controls, thin soil capping or other risk management options.
9. Collect samples that represent environmental media (soil and sediment) and the related conditions to support the following activities;
    a. Bioavailability Assessment Activities (BA);
    b. Human Health Risk Assessment Work Plan Activities (HHRA);
    c. Ecological Risk Assessment Work Plan Activities (ERA);
10. Collect samples that represent environmental media (soil and sediment) and the related conditions to support public information and participation activities.

5.5.2 Level of Quality Effort

The overall QA/QC objective during the UTR Project is the use and implementation of procedures for sample collection, field documentation, sample custody, analytical methodology, field and laboratory QA/QC, and reporting that provide results which are legally defensible and based on sound engineering and science. The overall QA/QC objective of the laboratory analytical program is to generate data that is scientifically defensible and of known precision and accuracy. Laboratory DQO for the UTR Project, expressed in terms of precision, accuracy, and completeness are given in the UTR Project QAPP. Field DQOs for UTR Project are summarized in Section 5.5.3 of this SAP.

5.5.3 Field Quality Objectives

Sampling precision and bias will be assessed through the collection of field duplicate samples. In general, 1 field duplicate and 1 field blank per 20 environmental samples or a minimum of 1 per sampling event will be submitted to the laboratory. The variation between field duplicate results should be no greater than ±20 percent for conventional parameters and ±35 percent for organics. Duplicates with Relative Percent Difference (RPD) values in excess of these limits maybe indicative of imprecision resulting from sampling techniques and results should be evaluated accordingly. Steps will be taken to correct potential sources of imprecision for any additional sampling but in these cases re-sampling will not occur. Accuracy in the field will be assessed by analysis of equipment blank rinsate samples. Equipment rinsate blanks which consist of deionized water rinsates of sampling equipment or containers, will be analyzed to indicate potential sample contamination from contaminated equipment. At least one equipment rinsate blank will be taken per sampling event.

5.6 QUALITY ASSURANCE PROJECT PLAN

A Quality Assurance Project Plan (QAPP) was developed by ATS for the UTR Project. The UTR Project QAPP includes information on project organization, responsibilities, sampling procedures, quality control checks, data management, and reporting. The QAPP is updated annually based on the work to be performed. The QAPP is incorporated into this document by reference.

5.7 HEALTH AND SAFETY PLAN

A Health and Safety Plan (HASP) was developed by ATS for the UTR Project activities. The HASP includes safety precaution information and emergency procedures. The HASP updated annually based on the work to be performed. The HASP is incorporated into this document by reference.

5.8 SURFACE WEIGHTED AVERAGE CONCENTRATION (SWAC) ANALYSIS

5.8.1 SWAC Methodology

A current condition SWAC analysis will be performed. This SWAC calculation will be prepared using the data collected from the UTR SAP to project TA concentrations for the following geomorphic features:

- in-channel
- floodplain
- natural levees
- historic natural levees
- wetlands
- low terraces adjacent to the river
- low terraces away from the river
- low intermediate terraces
- intermediate terraces adjacent to the river
- intermediate terraces away from the river
- high terraces adjacent to the river
- high terraces away from the river

- upper high terraces adjacent to the river
- upper high terraces away from the river
- upland away from the river

5.8.2 Current Condition SWAC Process

The current condition SWAC for the UTR Project will be developed by applying knowledge of the geomorphology of the river system together with detailed topographic information for the river and mapping of in-channel sediment to delineate boundary conditions for the flowing channel and overbank areas. "Like areas" will be established based on the relationship of the overbank features to the river channel. SWAC polygons will be assigned for "like areas" of in-channel deposits, floodplains or terraces based on their similarity as depositional environments.

The dynamic nature of the in-channel deposits requires a current sediment mapping. As part of this SAP, preliminary sediment mapping will be completed to map the in-channel soft sediment deposits, non-soft sediment bottom (sand), and gravel/cobbles/boulders bottom. This will be produced graphically to illustrate the in-channel conditions. This map will be used to assign polygons for each distinct deposit type (i.e., soft sediment, non-soft sediment, and gravel/cobbles/boulders). For the UTR project, a "distinct soft sediment deposit" definition will be established based on TA concentrations and related risk factors. Each in-channel soft sediment polygon will be assigned a TA concentration either from a sediment sample collected in that soft sediment deposit or a "proxy" value from a similar soft sediment deposit. Likely parameters used to establish similarity, and therefore suitability of a particular proxy value, include: relationship to meander bends, channel gradient, channel width, soft sediment texture, and proximity within a channel reach.

For in-channel areas with no soft sediment deposits or with soft sediment deposits smaller than the "distinct soft sediment deposit" threshold defined for this project, a "default non-soft sediment" concentration will be assigned. For the UTR this default value will need to be established based on measured values for hard packed sand. For in-channel portions of the river that have a channel bed consisting of gravel, cobbles, boulders or bedrock, a "default rock" concentration will be established and assigned. These "default" concentrations for non-soft sediment areas will be established and agreed upon.

The SWAC calculation used for overbank soil applies the soil concentration for the polygon to an assigned erosion factor (EF) reflecting potential to erode, an assigned attenuation factor (AF) based on proximity to the aquatic environment and other potential factors. If a sample concentration falls below the detection limit, one half of the detection limit will be used for the sample value. The adjusted concentration will be multiplied by the square footage of the polygon to obtain a "TA concentration times Area" number. The SWAC value is the sum of the adjusted "TA concentration times Area" numbers divided by the sum of the Area for a reach of the river or entire river section. The total SWAC for each Reach will be calculated by combining the total sum of the products of area and the adjusted concentration divided by sum of all areas.

During the field investigation, the geomorphologic data, soil/sediment profile information, TA concentration data, and erosion potential data will be used to develop a more accurate existing conditions SWAC. The existing conditions SWAC model will be updated on a near-real-time basis to optimize the sampling and analysis efforts prior to demobilization from the project area.

6. SCHEDULE

This section describes the implementation schedule for the *GeoMorph*™ SAP activities. The implementation schedule was developed based on the current understanding of work processes, regulatory review process, and stakeholder involvement. Time frames provided in the schedule are based on calendar days. The implementation schedule for this SAP is as follows:

- June 30, 2006 – Submit Revised Upper Tittabawassee River *GeoMorph*™ SAP to MDEQ
- July 6, 2006 – MDEQ Approval of Upper Tittabawassee River *GeoMorph*™ SAP
- July 17, 2006 – Commence Upper Tittabawassee River *GeoMorph*™ SAP Field Activity
- August 10, 2006 – Submit Bi-Monthly Status Report on Work Plan Progress to MDEQ
- October 10, 2006 – Submit Bi-Monthly Status Report on Work Plan Progress to MDEQ
- October 27, 2006 - Complete Upper Tittabawassee River *GeoMorph*™ SAP Field Activity
- November 30, 2006 – Submit Quarterly Monitoring Report to MDEQ
- December 10, 2006 – Submit Bi-Monthly Status Report on Work Plan Progress to MDEQ
- February 1, 2007 – Submit Upper Tittabawassee River *GeoMorph*™ Site Characterization Report
- February 10, 2007 – Submit Bi-Monthly Status Report on Work Plan Progress to MDEQ

The general parameters and assumptions used for developing this schedule are noted below:

- Access agreements are needed before field activities can take place on private properties. No samples will be collected until access agreements are in place to permit the necessary sampling. A time frame of 60 days was assumed for obtaining these access agreements prior to sampling. This includes 30 days to pursue access to locations identified in this SAP. Dow will make its best efforts to obtain access, but cannot control the response time of the third parties involved.
- The timeframes for activities performed by Dow are based on the scope of investigations outlined in this SAP and current standards of practice, such as: field preparation/mobilization time is necessary prior to all field events. This includes time to assemble and prepare a field team, procure subcontractors, and gather field equipment and supplies. The duration for field preparation/ mobilization activities is estimated to be approximately 14 days.
- Field sample collection activities have been scheduled with consideration for seasonal effects and to maximize the summer of 2006.

- This SAP will be implemented on a NRT basis. Information will be exchanged with MDEQ and USEPA on a mutually agreed upon schedule. Document deliverables will be prepared in time frames that align with their content, complexity, and decision-making needs. Sufficient time is needed to conduct internal reviews/revisions and to verify the quality of all information presented.

Since this SAP will be implemented on a NRT basis, it has been assumed MDEQ review and approval periods will be mutually agreed upon--but in general--will facilitate the NRT decision making process. Information exchange and MDEQ review and approval periods are considered “critical path” activities, and have the potential to affect the overall schedule because subsequent activities may not be able to start until approval for specific tasks or investigation areas is received.

Dow will make all reasonable and best efforts to schedule and sequence activities to complete work in a timely manner, including adjusting activities to try and compensate for delays in work due to matters outside Dow’s control (for example, access agreements, force majure, weather) if possible.

Sampling cannot begin until access is granted by property owners, the process of obtaining access agreements to the private properties where planned samples are located is a critical path item. Obtaining access agreements will be a very time-consuming field preparation activity. Based on the compressed timeframe for sampling activities associated with this SAP, the process of gaining property access was initiated during the first quarter of 2006. Should access to a property be denied, an attempt will be made to move the location to a suitable alternative property and access to this property will be pursued. Once an access agreement is in place with a property owner, the sample location(s) on that property are considered finalized. The final step of field preparation/mobilization is surveying and marking sample locations and clearing underground utilities (through Michigan MISS DIG) at all subsurface sampling locations. This will begin as soon as all necessary access agreements have been secured and will continue throughout the sample collection process. Samples will need to be collected in close time proximity to surveying/location marking to minimize the chance that marked locations on private or publicly accessible property will be disturbed, and thus eliminate the need to be resurveyed and remarked in order to collect the sample.

Laboratory analysis of environmental samples will take place in an ongoing manner throughout the sample collection event and will be completed on “rapid turnaround” NRT basis. Analytical validation of all laboratory results obtained during the implementation of this SAP will also take place on an ongoing basis and will also be completed on a “rapid turnaround” NRT basis.

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8. GLOSSARY

Accretion	The gradual addition of new land to old by the deposition of sediment carried by the water.
Aquifer	A subsurface strata or zone that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.
Aquitard	A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to wells or springs, but may serve as a storage unit for groundwater.
Bathymetry	The measurement of the depth of bodies of water.
Bedload	The part of a river's load that is moved on or immediately above the stream bed, such as the larger or heavier particles (boulders, pebbles, gravel) rolled along the bottom; the part of the load that is not continuously in suspension or solution.
Benchmark value	Published generic risk-based values for human and ecological exposure.
Confluence	The point where two or more rivers meet.
Cut bank	The steep or overhanging slope on the outside of a meander curve. It is produced by lateral erosion of the river.
Flashy	River flow regime characterized by a rapid rate of change.
Floodplain	That portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regimen of the river and is covered with water when the river overflows its banks at flood stages. The estimated 8-year and 100-year Floodplains represent the extent of the floodplain inundated during floods with recurrence intervals of 8 years and 100 years, respectively.
Fluvial	Of or pertaining to rivers.
Geochronology	Study of time in relationship to the history of the earth.
Geomorphic feature	An identifiable landform such as a levee or a terrace.
Geomorphic polygon	The two-dimensional mapped location of a geomorphic feature.
Geomorphology	The science that treats the general configuration of the earth's surface; specifically, the study of the classification, description, nature, origin, and development of landforms and their relationships to underlying structures and the history of geologic changes as recorded by these surface features.
Hazardous substance	Any substance that the Michigan Department of Environmental Quality demonstrates, on a case-by-case basis, poses an unacceptable risk to public health, safety, or welfare, or the environment, considering the state of the material, dose-response, toxicity, or adverse impact on natural resources.
Hydrophobic	Lacking strong affinity for water.
Lacustrine	Sediment deposited in a lake environment.
Morphology	The observation of the form of lands.
Natural levee	A ridge or embankment of sand and silt, built by a river on its floodplain along both banks of its channel, especially in times of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load.

Overbank deposit	Silt and clay deposited from suspension on floodplain by floodwaters that cannot be contained within the river channel.
Palustrine	Pertaining to material growing or deposited in a marsh.
Pedogenic	The natural process of soil formation and development, including erosion and leaching.
Photolysis	Chemical decomposition induced by light or other radiant energy.
Photo-oxidation	Oxidation under the influence of radiant energy (as light).
Point bar	One or a series of low, crescent-shaped ridges of sand and gravel developed on the inside of a growing meander of a river or stream by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.
Potential Constituent of Interest	Master list of chemicals of which a subset will become a target analyte list.
Sediment	Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, or ice, and has come to rest on the earth’s surface either above or below sea level.
Shear stress	Force produced at the sediment bed as a result of friction between the flowing water and the solid bottom.
Soil	A natural body consisting of layers or horizons of mineral and/or organic constituents of variable thicknesses, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties and their biological characteristics; at least some of these properties are pedogenic.
Splay	Deposit typically composed of sandy or silty material found in floodplain areas where floodwaters breach levees or banks formed by reduction in velocity as floodwaters spread out.
Streamline	Predicted flow path of a particle under different flow conditions.
Suspended load	Finer particles that are suspended in the water column.
Target analyte list	The subset of the potential constituent of interest list of which will be analyzed on select soil and sediment samples
Thalweg	The line drawn to join the lowest points along the entire length of a river bed or valley.
Till	Unstratified drift, deposited directly by a glacier without reworking by meltwater, and consisting of a mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.
Unconsolidated	A sediment that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either at the surface or at depth.

9. ACRONYMS AND ABBREVIATIONS

°F	Degrees Fahrenheit
1984 Report	*Point Sources and Environmental Levels of 2,3,7,8-TCDD (2,3,7,8 – Tetrachlorodibenzo-p-Dioxin) on the Midland Plant Site of The Dow Chemical Company of Midland, Michigan* (November 5, 1984)
ANOVA	Analysis of variance
ATS	Ann Arbor Technical Services
cfs	Cubic feet per second
COI	Constituent of interest
CSM	Conceptual Site Model
DDT	4,4’-(2,2,2-Trichloroethane-1,1-diyl)bis(chlorobenzene)
DGPS	Digital global positioning system
dioxin	Polychlorinated dibenzo-p-dioxin
Dow	The Dow Chemical Company
DQO	Data quality objective
ERA	Ecological risk assessment
FEMA	Federal Emergency Management Agency
furan	Polychlorinated dibenzo-p-furan
GPS	Global positioning system
HHRA	Human health risk assessment
License	Hazardous waste management facility operating license
LiDAR	Light Detection and Ranging
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
mg/L	Milligrams per liter
Midland Plant	The Dow Chemical Company Midland Plant in Midland, Michigan
MNFI	Michigan natural features inventory
msl	Mean sea level
MSU	Michigan State University
PAH	Polynuclear aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCOI	Potential constituent of interest
ppt	Parts per trillion or picograms per gram
QAPP	Quality assurance project plan
QA/QC	Quality assurance/quality control
RGIS	Revetment groundwater interception system
RI/WP	Remedial investigation work plan: CH2M Hill, 2005c
S3TM	*Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria*: MDEQ 2003b
SAP	Sampling and analysis plan

Scoping Study	*Tittabawassee River Floodplain Scoping Study*: CH2M Hill 2005a
SVOC	Semivolatile organic compound
SWAC	Surface weighted average concentration
TA	Target analyte
TAL	Target analyte list
TCDD	2,3,7,8-Tetrachloro-dibenzo-p-dioxin
TEF	Toxic equivalency factor
TEQ	Toxic equivalent quotient
TOC	Total organic carbon
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTR	Upper Tittabawassee River
VOC	Volatile organic compound
WHO	World Health Organization
WWTP	Wastewater treatment plant